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Introduction

The Alberta Office of Coal Research and Technology was established January 20, 1984, by Ministerial Order under the Department of Energy and Natural Resources Act.

Its purpose is to co-ordinate the Alberta government funding needed to identify, investigate and develop coal-related technologies considered to be commercially important during the next decade. Its goals are:

- to enhance the competitiveness of Alberta's coals in international markets;
- to minimize the environmental impact of the production or use of coal in Alberta; and
- to create new uses for Alberta's coals.

Appointed to the Office are R. Douglas McDonald as Chairman, and Garnet T. Page and Michael A. Ward as Members. T. David Brown represents Energy, Mines and Resources Canada as an observer and participates in project reviews.

Initial funding of $20 million was allocated from the Alberta/Canada Energy Resources Research Fund to provide financial support for research projects.

A successful Alberta Coal Research Strategy depends on the wise collaboration of government, industry and the research community.

Chairman's Report

During most of 1987, Alberta coal producers responded to depressed coal prices by continuing to improve their operating efficiencies and productivity. This put them in a good position to provide increased quantities of coal in response to rising demand during the first three months of 1988. Thus, the fiscal year ended optimistically.

Within the coal industry, it is apparent that more companies support the idea that technology development and application have become, and should remain, essential elements of a healthy industry. This not only improves productivity, but helps create new market opportunities. The Office, therefore, remains committed to working closely with coal producers and users, ensuring the timely development and application of new technology to enhance the competitiveness of Alberta coals in provincial, national or international coal markets.

This year, as in 1986/87, the Office continued to operate under a tight budget. Within this limitation, and in recognition of the current interest in promoting the use of western Canadian coals in Ontario, projects were launched to assess technology for reducing coal transportation costs, particularly those which industry is unlikely to assess on its own. The two principal options under study are coal-oil pipelining and coal-water pipelining using existing pipelines. Also initiated this year was the development of a computer-based coal supply model. It assesses the effects various coal supply and transportation options have on the delivered cost of Alberta coals in Ontario and other market locations.

In addition to these transportation studies, the Office began consolidating its other activities into three major programs. They are: Strategic Research Program, Institutional Research Program and Coal Research Grants Program.

Within the Strategic Research Program, projects jointly funded with industry are being developed in a manner consistent with industry priorities. This is accomplished through a series of joint industry/government technical committees. These committees comprise representatives of companies and governments who share mutual interests and are willing to fund research and development projects jointly.

By March 31, 1988, six technical committees had been organized under the following topics:

Geomechanics;

Fine Coal Cleaning;

Spontaneous Combustion;

Coal Gasification;

Coal-Fired Steam Generation for Heavy Oil Recovery; and

Sorbent Injection.

It is likely that additional technical committees will be formed in the following areas:

Coal/Heavy Oil Co-processing; and

Upgrading of Low-Rank Coals.

The Institutional Research Program supports the development and improvement of technical capability at the Alberta Research Council and the Coal Mining Research Company. This program should assist these organizations in responding to the needs of government and industry. Support from the Office includes funding to permit these organizations to develop or improve their competence in new technologies and remain abreast of developments in particular fields.

The Office is continuing to encourage scientific excellence in fundamental coal research through the Coal Research Grants Program. This program provides funding to university researchers and has supported 19 projects thus far.

The results of many investigations supported under these three programs are available to industry and other interested parties through technology transfer publications. Five of these are available from the Office or the Alberta Energy/Forestry, Lands and Wildlife Information Centres. As well, a one-day coal research workshop was sponsored by the Office this year. It was held at the University of Calgary and included presentations by university, institutional and industry researchers who described Office-supported projects.

The workshop was followed by a one-day symposium on the spontaneous combustion of coal. Three international speakers, along with several from Canada, provided a stimulating background for this little understood, but very important, phenomenon. The symposium led to the establishment of the Spontaneous Combustion Technical Committee.

During 1987/88, the Office received 42 requests for research funding. Twenty-seven were approved for funding. In addition, financial support was continued for 32 previously approved projects. Financial contributions by the Office totalled $4.6 million, whereas contributions by industry and other groups totalled $5.3 million. The latter represents 54 per cent of total research expenditures for approved projects.

The Office worked closely with the Intergovernmental Secretariat to the Action Committee on Western Canadian Low-Sulphur Coal to Ontario to ensure that Office activities supported the Secretariat's initiatives. Currently, funding is being provided by the Office for several projects, and several technical committees are actively developing projects within this initiative.

The Office is also encouraging closer collaboration and integration of research activities and administration at the Coal Research Centre, Devon, and with the coal-related activities of the Canada Centre for Mineral and Energy Technology in Ottawa.

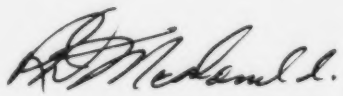
Collaboration among research and development organizations in Alberta, throughout Canada and overseas is also encouraged by the Office. Financial support is provided through the Alberta Research Council for collaborative work on liquefaction of Alberta coals involving Canada and Japan. This has resulted in the use of Alberta subbituminous coal in pilot-scale tests of the NEDOL process in Japan. Discussions are under way to include coal gasification studies in this joint program.

With technical assistance by the Alberta Research Council, the Office is participating in an International Energy Agency-sponsored project to investigate the fundamentals of coal combustion.

Another international initiative of the Office, in conjunction with Energy, Mines and Resources Canada, several Canadian companies, one German firm and the Government of the Federal Republic of Germany (FRG) is investigating the potential of coal-water slurry technology in reducing coal transportation costs. Opportunities to collaborate with the FRG government on coal gasification, and with the Government of France on other subjects, are being explored.

It became apparent in 1987/88 that manufacture of coal-related equipment in Alberta can contribute to the provincial government's diversification objectives. Therefore, the Office has begun to place greater emphasis on this aspect of the coal business.

Day-to-day administration of Office projects is provided by staff of the Alberta Department of Energy, Scientific and Engineering Services and Research Division. Additional assistance and considerable support and co-operation have been provided by the coal industry, the Coal Research Technical Panel, the Interdepartmental Group for Coal Research and The Coal Association of Canada.



R. Douglas McDonald
Chairman

Background

Alberta's coal industry provided an important energy source during early development of the province, and it continued to contribute significant economic activity until about 1950 when the coal market collapsed. In the mid-1960s, a resurgence occurred in the export market for metallurgical coal and in the provincial market for thermal coal. By 1974, annual production had risen to 9.5 million tonnes.

From 1975 to 1985, Alberta's raw coal production rose steadily, reaching 27.7 million tonnes, where it remained throughout 1986. It rose again in 1987, reaching 28.8 million tonnes. Marketable coal deliveries in 1987 amounted to 25.7 million tonnes, an increase of 3 per cent over 1986.

Income earned by Alberta's coal producers is derived from exports of bituminous coals, and combustion of subbituminous coals by Alberta utility companies which produce more than 91 per cent of Alberta's electricity. Approximately 2 600 people are directly employed by Alberta's coal producers.

These statistics emphasize some of the benefits and the importance of Alberta's coal industry, but there are other advantages to having a healthy coal industry in the province. For example, coal mines provide a very high economic and social return on the land used. Also, the sale of coal to other countries improves Canada's trade balance, contributes to expansion of the provincial transportation network, and fosters growth in the provincial construction industry during periods of expansion. Other direct benefits include financial contributions to the three levels of government, and the purchase of goods and services within Alberta.

It is expected that Alberta's coal industry will continue to encourage the growth of secondary industries, provide a reliable and economic energy source for the recovery of the province's heavy oils and bitumen, and make other significant contributions to the province's economic base.

To optimize these benefits, however, coal-exporting companies must first deal with concerns such as the current oversupply of coal world-wide. This competitive environment is worsened by economic conditions in Japan, Canada's largest single coal export market, where demand for metallurgical coal, and the price that customers are willing to pay, have remained low. By year-end, however, deliveries were higher than during the same period one year ago.

In the case of thermal coal exports, offshore markets are developing more slowly than expected because of lower electricity demand and low oil prices in international markets. However, increased coal sales in Ontario are anticipated as a result of the recommendations of the Action Committee on Western Canadian Low-Sulphur Coal to Ontario.

Today's difficult market conditions make it essential that Alberta coal producers use the most efficient and economical technologies available in coal exploration, production, preparation, upgrading, transportation and marketing. Increasingly, overseas customers are demanding coal and coal products that exhibit specific qualities and behaviour. This means that coal producers must know more about the combustion characteristics of their products. They must also be involved in the development of new technologies such as agglomeration, coal-water fuels and other upgrading processes that will produce coal products tailored to market requirements.

The Alberta coal industry's response to these difficulties and challenges is expressed in the Alberta Coal Research Strategy, published November 1983, which was the result of extensive discussions among individual companies and the provincial government. Later, the Alberta Office of Coal Research and Technology was established. Subsequently, industry proposals submitted to the Office resulted in research and development projects jointly funded with the Alberta government. Additional support, designed to foster fundamental research beneficial to the coal industry, is provided by the Alberta Office of Coal Research and Technology's Coal Research Grants Program.

This is supplemented by institutional research projects funded by the Office and carried out by the Alberta Research Council and the Coal Mining Research Company.

Another important function provided by the Alberta Office of Coal Research and Technology is the co-ordination of coal research and development activities within Alberta, as well as between Alberta, national and international agencies.

This has led to better integration among the various coal research groups in Alberta. Also, it has resulted in a stronger focus on the needs of industry, and has produced international contacts and greater international co-operation.

The Office has directly influenced research and development activities within Alberta by funding projects jointly with individual coal-producing companies or groups of companies, other government agencies, universities, private research organizations, consultants, utilities, equipment suppliers and agencies in other countries.

The Office is influencing coal research and development elsewhere by participating on various national and international committees, including the International Energy Agency's Working Party for Fossil Fuels and the Canada/Japan Coal Conversion Research and Development Committee.

Coal Research Strategy

Research Rationale

Consistent with the views of the Government of Alberta, the Alberta Office of Coal Research and Technology believes the private sector should take the lead in identifying and managing appropriate research and development programs, as well as implementing and commercializing the results. The role of the Office and other government agencies such as the Alberta Research Council, along with universities and research organizations such as the Coal Mining Research Company, is to support the private sector as necessary to achieve the desired technical results most efficiently.

While there is a recognized need for long-term research and development, as well as basic research to facilitate a better understanding of coal properties and uses, the critical time for commercial expansion and economic development of the province's coal resources is from 1992 to 1998. During this time, growth in thermal coal use throughout the world is probable, but Alberta's share of the market will be influenced by increased competition from other coal exporters. To what extent this expansion of thermal coal use can be realized, however, will depend on the prices of other energy supplies, particularly natural gas, oil and nuclear power, and the relative social and environmental acceptance of coal versus other fuels.

Towards this end, in 1984 the Alberta Office of Coal Research and Technology identified initial funding through the Alberta/Canada Energy Resources Research Fund of approximately $20 million in support of agreed research, development or demonstration projects. It was anticipated that similar funding would be forthcoming from the private sector. A portion of the funding is being used for long-term or fundamental research directed toward innovative technologies related to production and use of Alberta coals.

Alberta must collaborate closely with research groups elsewhere to ensure that maximum benefit is derived from the total international coal research and development effort, and to define its intermediate- and long-term plans within this context.

In pursuing its objectives, the Alberta Office of Coal Research and Technology works closely with The Coal Association of Canada and the Alberta coal industry to establish research and development priorities. In addition, the Office maintains world-wide contacts with researchers engaged in coal-related studies.

Administrative Framework

The Alberta Office of Coal Research and Technology does not have in-house facilities to carry out research projects. Rather, its primary role is to provide funding for approved coal research projects. Therefore, procedures have been established to ensure sound project management and financial control of approved projects. For each project, specific agreements are signed which define the terms and conditions under which the project will be conducted and funded. These agreements also define the respective rights of new project technology ownership and use.

Each research proposal received by the Office is given thorough consideration and a prompt response. Proposals considered to fall within the Alberta Coal Research Strategic Plan are discussed in detail with the applicant, and are often referred in confidence to one or more experts for detailed technical review.

An Alberta government interdepartmental group has been established to review and comment on the implications of the proposed research. This group includes representatives from the Energy Resources Conservation Board and the departments of Forestry, Lands and Wildlife, Economic Development and Trade, Environment, and Community and Occupational Health.

Approval of research proposals by the members of the Alberta Office of Coal Research and Technology is based on the results of these reviews, relative funding contributions and the likelihood that proposed research will contribute to achieving the goals of the Alberta Coal Research Strategic Plan. Those projects funded by the Alberta/Canada Energy Resources Research Fund (A/CERRF) are subsequently submitted to the A/CERRF Committee for approval.

Applications received within the scope of the Alberta Coal Research Grants Program are reviewed by the Alberta Office of Coal Research and Technology to ensure they are consistent with the objectives of this program. Applications are then considered in detail by the Coal Research Technical Panel, which makes recommendations to the Office regarding the scientific merit, associated funding, and the extent to which the application should be supported by the Office.

Technical Committees

While the overall objectives of the Alberta Office of Coal Research and Technology are still guided by the Alberta Coal Research Strategic Plan, it is recognized that the process of deciding which projects ought to be initiated requires a flexible administrative structure.

Therefore, a process has evolved to assist program planning. It involves consultation with industry to identify issues, priorities and potential partners of the Office in new programs and projects. If, as the result of this consultative approach, the potential for development of new technology is sufficiently high to attract industry participation and funding, a broad plan for research is formulated and a technical committee is established to oversee the program. Typically, the executive of a technical committee comprises co-chairmen representing industry and the Office, a consultant as secretary and a project manager.

Following establishment of a technical committee, project specifications are developed and calls for proposals are issued to qualified firms and research institutions.

After proposals are received and reviewed by the technical committee, working groups are normally formed to manage individual projects. These groups usually comprise companies which are interested in a particular issue and are willing to contribute funds. Working groups pursue problems, enter into contracts, form joint ventures among themselves and seek funding from governments.

Generally, government funding agencies provide 50 to 60 per cent of the funds needed for precommercial research (defined as investigations which precede commercial-scale developments). Occasionally, working groups will proceed without government participation. Funding arrangements are kept flexible to accommodate the needs of participants and the nature of the problem under investigation. When projects are completed, working groups are disbanded.

Full reports on projects are available only to those participants who contribute funds. The question of confidentiality is left to the discretion of working groups. Summaries of results can be released to others, particularly to attract additional participants to later phases of investigation.

Technical committees act as co-ordinating and collaborative agencies. They make recommendations regarding courses of action and whether projects ought to be pursued. Then, any decisions as to project funding are made by senior management of participating companies and agencies.

Research Priorities

Since the Alberta Coal Research Strategy was prepared in 1983, several important events have occurred which could significantly affect Alberta coal producers, particularly those depending on export sales.

In Japan, a drop in demand for steel and changes in technology have allowed steel producers to use lower quality, "soft" or "weak" coking coals. This is forcing Alberta producers of high-quality coking coals to lower their prices. This trend is expected to continue and will result in new specifications for coking coal quality and performance.

Ontario Hydro is considering the use of more low-sulphur western Canadian coals to help meet provincial acid gas emission guidelines and establish a reliable domestic coal supply. This has resulted in a commitment by both industry and government to reduce the delivered cost of western Canadian coal in Ontario.

In Alberta, emphasis is being placed on expanding opportunities to use coal in place of natural gas to generate steam for enhanced oil operations.

World-wide, the development of new coal use technologies is generating demand for certain types of internationally traded thermal coals. Suppliers are now aware that they should be providing thermal coals tailored to these new systems. Success in these markets will depend on having a better understanding of the performance characteristics of coal products under different operating conditions. Coal gasification developments are of particular interest to the Office and Alberta coal producers.

These changes have been influential in bringing about some modifications to the research priorities of the Alberta Office of Coal Research and Technology. Currently, those priorities are as follows:

- to enhance opportunities for sales of Alberta coals in Ontario by ensuring the availability of competitively priced, high-quality products. This includes assessing the potential of alternative technologies and transportation systems, as well as pursuing prospective market opportunities.
- to enhance opportunities for sales of Alberta coals in international markets by ensuring that the performance characteristics of these coals in a variety of applications are fully understood, and that improved products are developed to meet the needs of emerging technologies. This includes encouraging co-operative, knowledge-sharing programs among Alberta coal producers, potential users and the developers of new technologies; and
- to expand opportunities to use coal in Alberta, particularly for producing and upgrading heavy oil and oil sands. Currently, several projects are under way to encourage the use of coal to displace natural gas for steam raising in enhanced heavy oil schemes.

Research Program

Introduction

Based on discussions with industry and the research community, the following research and development program areas have been identified as opportunities for further investigation. They are as follows:

Resource Evaluation

Mining

Preparation and Upgrading

Combustion

Liquefaction

Gasification

Transportation

Environment

Markets

In each of these areas, workers' health and safety during both the research stage and subsequent commercial-scale applications must be considered.

Resource Evaluation

In applying technology to the challenge of making Alberta coals more competitive in various markets, a significant opportunity is posed by the need to match coal quality to coal uses and reduce costs related to coal exploration and mine planning.

Traditionally, attempts to find coal deposits have involved outcrop inspections and expensive core-hole drilling to obtain information on subsurface rock geometry, hydrogeology and coal quality. The latter is particularly important because it indicates whether coal seams found by exploration methods are commercially valuable; however, recent customer demands for tighter coal specifications are causing more core holes to be drilled to isolate coals capable of satisfying particular requirements. This increases the costs of coal exploration and is an important impetus behind current research into alternative geophysical and geostatistical methods of evaluating coal quality while the coal is still in the ground.

In this approach, researchers are attempting to correlate seismic, direct current electric, magnetic and electromagnetic data from above-ground surveys of prospective coal fields with laboratory analyses of drilled cores. In this way, it is believed that less expensive methods will be found to locate coal and evaluate its characteristics.

Since 1985, the Alberta Office of Coal Research and Technology has helped fund seven coal resource evaluation projects, three of which were completed previously. The four remaining projects, which were in progress this year, are described in the following section.

Alberta Coal Geology Project[1]

ALBERTA RESEARCH COUNCIL, EDMONTON

The Alberta Coal Geology Project is jointly funded by the Alberta Office of Coal Research and Technology and the Alberta Research Council. Its overall objective is to improve the Alberta coal information base in areas where it is deficient so that industry and government can focus better on future coal development plans.

From 1974 to 1986, a coal exploration program carried out by the Alberta Research Council made a general assessment of coal reserves in Alberta's plains region, including the development of methods to predict the distribution, thickness and continuity of

[1] An Institutional Research Program project.

coal seams. The current three-year project was begun in 1986/87, placing greater emphasis on coal quality in the plains, foothills and mountain regions. The project comprises four subprojects as follows:

Quality of Plains Coal

In response to the need by coal companies and planners to predict confidently the properties of coal at varying distances from known data points, this project is developing geostatistical and geological models for the plains region. Specifically, an understanding is being developed of the factors controlling coal quality in the Drumheller (Horseshoe Canyon Formation) and Ardley (Paskapoo Formation) coal zones.

This year, six coal seams at the Highvale mine site were examined to quantify the degree of variability in coal quality factors.

This included proximate analyses from 315 data locations. Considerable differences were found from seam to seam, suggesting that data on the sampled interval, as well as the location, are important parameters for assessing variations in coal quality. Also at the Highvale mine, a study of the vertical variation in coal facies assemblages was begun, based on maceral and miospore distributions. These were compared with proximate and ultimate analyses.

A Regional Evaluation of Coal Quality in the Foothills and Mountains

In earlier coal geology investigations, a broad synthesis of coal quality data for the plains region was made, but no such synthesis has been made of existing data from the foothills and mountains. Therefore, this project aims to develop a better geologic understanding of coal quality in those regions.

This year, a regional statistical and geological analysis was completed of all publicly available coal quality data for the foothills/mountains regions in southern Alberta. A similar study for the northern portion of the coal-bearing area of the province was begun.

Foothills and Mountains Coal Quality - Local Study

In this project, a detailed study is being made of coal quality variations in the structurally deformed coal-bearing sequence.

This is being done to establish baselines for procedures to assess coal quality, to compare coal quality data from different areas of the foothills and mountain regions, and to determine the effects of folding and faulting on coal quality.

Detailed sedimentological studies were done for strata immediately overlying and underlying the major economic seam of the Cadomin-Luscar coal field. Some variation in ash and sulphur can be explained by the sedimentary environment. Ash contents have been locally increased by tectonic shearing. Analyses of the various quality parameters show that only sulphur and nitrogen are normally distributed.

Data Base Management and Natural Resources Information System

In support of the other projects in the program, a data base will be designed and maintained in a form useful to planners and resource managers. Integration of data from the Energy Resources Conservation Board, coal companies and the Alberta Research Council began this year, using the INGRES data management system. Also, development of a Geographic Information System (GIS) pilot project was begun by mapping an area west of Edmonton that included the Genesee, Highvale and Whitewood mines.

Publications

Langenberg, C.W., W.D. Kalkreuth and C.B. Wrightson. 1987. *Deformed Lower Cretaceous Coal-Bearing Strata of the Grande Cache Area, Alberta.* Alberta Research Council Bulletin No. 56.

Langenberg, C.W., D.E. Macdonald and R.J.H. Richardson. 1986. *Geological Studies of Coal in Alberta : Status Report.* Alberta Research Council, Open File Report 1986-14.

Macdonald, D.E., C.W. Langenberg and R.S. Strobl. (In Press). *Cyclic Sedimentation in the Lower Cretaceous Luscar Group and Spirit River Formation of the Alberta Foothills and Deep Basin.* Canadian Society of Petroleum Geologists.

Macdonald, D.E., C.W. Langenberg and R.S. Strobl. 1988. *The Importance and Recent Advances in Geological Coal Quality Studies in Alberta.* Prepared for Canadian Institute of Mining and Metallurgy Annual General Meeting, May 1988.

Macdonald, D.E., N. Chidambaram, C.W. Langenberg, G.B. Mandryk, C.E. Sterenberg and A. Cameron. 1987. *A Regional Evaluation of Coal Quality in the Southern and Central Foothills/Mountains Region of Alberta.* Alberta Research Council Open File Report 1987-9.

Richardson, R.J.H., R.S. Strobl, D.E. Macdonald, J.R. Nurkowski, P.J. McCabe and A. Bosman. 1988. *An Evaluation of the Coal Resources of the Ardley Coal Zone to a Depth of 400 m in the Alberta Plains Area.* Alberta Research Council.

In-Seam Coal Characterization[1]

COAL MINING RESEARCH COMPANY, DEVON

Overseas buyers of Alberta coal are demanding more consistent product specifications than in the past. This causes Alberta coal producers to drill more core holes into coal seams, followed by more laboratory analyses to obtain information about coal quality. As the number of core holes per coalfield rises, so too do the costs of developing that field.

An alternative approach is to obtain coal quality information by less expensive geophysical methods. In an earlier phase of this project, two primary methods of obtaining coal quality characteristics while the coal is still in the ground were identified from a literature survey. They involve: (1) nuclear spectroscopy based on elemental analysis, and (2) an empirical method using geophysical logs and interpretive models.

In reviewing the available nuclear spectroscopy systems, it was concluded that existing hardware is not capable of detecting all of the most important constituents of Alberta coals, but the potential does exist for developing equipment to provide the required information.

Meanwhile, several coal producers supplied logs of geophysical data and corresponding laboratory data on coal quality, allowing attempts at developing interpretive models to proceed, based on commercially available computer software.

Trials of interpretive programs to determine their suitability revealed that a good, qualitative correlation exists between logged geophysical density and laboratory-derived material densities, ash content and calorific value for coal from an Alberta plains mine.

Multi-log methods produced less satisfactory correlations partly because of difficulties in estimating required mathematical constants. It was also found that a lack of consistency in obtaining the geophysical information in the field and relating it to laboratory analyses contributed to the data scatter.

The correlations, although very promising, were not precise enough to predict accurately the desired parameters in place of laboratory analysis.

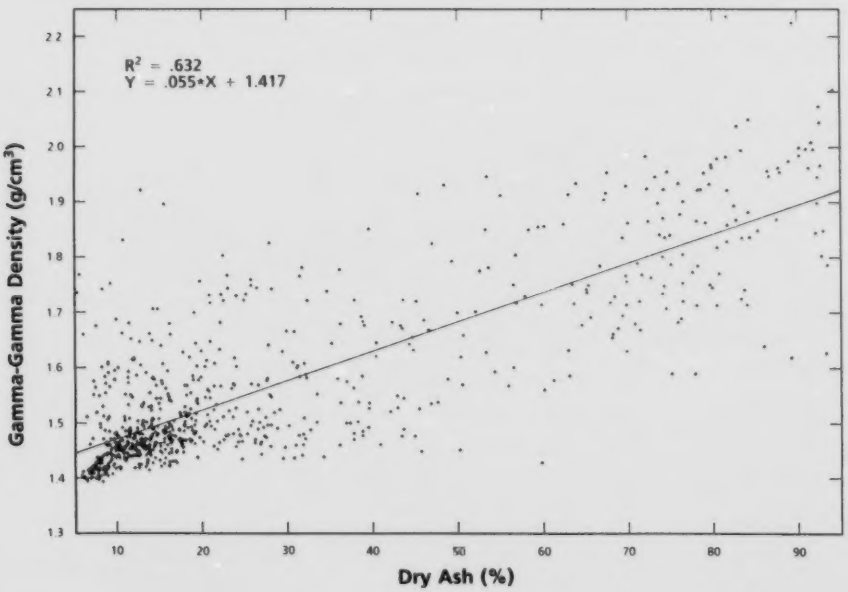
Publications

Wilson, R.A. 1986. *In-Seam Coal Characterization: Phase I.* CMRC Report M08602.

Wilson, R.A. and R.G. Chopiuk. 1987. *In-Seam Coal Characterization: Phase II.* CMRC Report M08602.2.

[1] An Institutional Research Program project.

Gamma-Gamma Density vs Dry Ash
Test Case – all holes



Downhole Geophysics[1]

TRANSALTA UTILITIES CORPORATION (CALGARY) AND OTHER PARTICIPANTS[2]

Surface mining of coal, the predominant method of coal extraction in Alberta, requires the removal of large quantities of overburden to expose the underlying coal seams. This operation is usually the most expensive aspect of open-pit coal mining in Alberta. As well, the stability of excavated highwalls and deposited spoil piles represents an important safety aspect of mine design.

In designing and planning a typical open-pit mine, overburden samples taken from exploration bore holes are analysed for physical characteristics that will affect mine design and cost. It is expensive, however, to drill bore holes and perform laboratory analyses. Therefore, mine designs are usually based on a relatively small number of bore holes. The limited information so obtained can lead to unexpected situations and require a certain amount of conjecture about overburden stability and materials handling.

An alternative to this is to use geophysical techniques, including bore hole methods, which are potentially less expensive ways of providing considerably more information on overburden characteristics. While instrumentation for downhole geophysical measurement is well established, it remains to be demonstrated that quantitative interpretation of data for physical characterization can be achieved for Alberta's coal-mining environment.

In this project, which was initiated in 1986, promising geophysical measurement methods were evaluated for their ability to provide geotechnical and hydrogeological information. Subsequently, coal-producing companies were asked to supply geophysical log data and corresponding measurements of geotechnical/hydrogeological properties to establish a data base from which correlations could be derived. While several correlations have been established, their widespread use is limited by the amount of statistical variation still remaining. Further work is required to investigate different data analysis methods using newly acquired geophysical information.

Furthermore, several new geophysical methods were identified for testing in subsequent field programs.

Publication

TransAlta Utilities Corporation. 1987. *Determining Geotechnical and Hydrogeological Parameters Using Downhole Geophysics in the Canadian Plains: Phase I.*

Seismic Modelling of Shallow Coalfields[3]

UNIVERSITY OF CALGARY (D.C. LAWTON), CALGARY

In recent years, experimentation with a technique known as surface reflection seismography has indicated that it could be used to search for and evaluate coal in situ, but its use has been limited to determining whether coal is present. This project is attempting to demonstrate that quantitative interpretation of coal reflection seismic data is possible. By first comparing synthetic seismograms with information from acoustic and density drillhole logs obtained from coal deposits, followed by two- and three-dimensional seismic modelling, it was anticipated that the thickness, geometry and number of coal seams in a deposit could be interpreted from seismic data.

Interpretation of field seismic logs, in conjunction with the results of numerical and physical modelling experiments, revealed that density contrasts between coal and host sediments were primarily responsible for the reflectivity characteristics of plains coal. Furthermore, studies of synthetic seismograms showed that small variations in seam thickness and separation significantly affected the overall seismic response. Signal resolution, however, was dramatically affected by the placement of acquisition equipment in the field. It was shown that near shot-receiver offsets are preferred in seismic exploration for shallow coals. Overall, it was concluded that reflection seismic surveys can be useful in mapping coal pinchouts and wash-out zones ahead of mining operations.

[1] A Strategic Research Program project.

[2] *Other participants are:* Atomic Energy of Canada Limited, Fording Coal Limited, Golder Associates, Klohn Leonoff Ltd., Manalta Coal Ltd., Monenco Consultants Limited, Piteau Associates, Saskatchewan Power, Suncor Inc., Syncrude Canada Ltd., Terracon Geotechnique Ltd., Alberta Research Council, Canada Centre for Mineral and Energy Technology, and the Alberta Office of Coal Research and Technology, assisted by the Coal Mining Research Company and the Geological Survey of Canada.

[3] A Coal Research Grants Program project.

Mining

With the exception of one mine in the mountain region, where a combination of surface and underground mining is used, all of Alberta's coal producers use surface mining to extract their coal. They are expected to continue with this relatively low-cost method for the next 25 years at least. To strengthen the competitive position of Alberta coals in international markets, however, it is believed that mining costs need to be reduced further.

Therefore, the most expensive element of surface mining, which is overburden removal, has been the subject of several research studies funded by the Alberta Office of Coal Research and Technology.

This has included investigations of the geotechnical properties of overburden and experimentation with a footwall anchoring method that proved to be substantially less expensive than conventional benching techniques.

Other mining-related subjects have been researched as well. In total, 11 coal-mining projects have been supported by the Office. Five of them were under way this year. They are described in the following section.

Footwall Anchoring[1]

SMOKY RIVER COAL LIMITED, GRANDE CACHE

In this project, 600 mechanical rock bolts and 1 764 tensioned rock anchors were used to support a steeply dipping footwall in an open-pit coal mine. Anchoring was accomplished at approximately 62 per cent of the cost of benching, which is normally used in such situations. Without anchoring, recovery of the coal would have been marginally economic.

Forty-seven survey prisms, nine surface extensometers, two bore hole extensometers, 23 load cells and two piezometers were used to assess the overall stability of the slope and provide warning of failures occurring along the footwall.

Although significant movement of the footwall was detected during the last month of the two-year mining activity, all the coal was removed from the pit. Approximately two months after mining was completed, the footwall failed.

In assessing the value of the various monitoring instruments, it was concluded that the survey prisms were the most effective, but the other instruments were essential for accurate assessment of slope behaviour and the effectiveness of remedial measures.

While the mining geometry, engineering geology and slope behaviour were unique to this location, the monitoring and slope assessment techniques used in this project may be applied to similar types of mining situations.

Publications

Smoky River Coal Limited and Piteau Associates Engineering Ltd. 1987. *Upper East Limb Open Pit Rock Anchoring and Slope Monitoring Project: Final Report.*

Martin, D.C. and P. Sheehan. 1988. *Assessment of Instrumentation Systems for a Footwall Slope at Smoky River Coal.* Annual General Meeting of CIM.

Fawcett, D., P. Sheehan and D.C. Martin. 1987. *Footwall Anchoring at Smoky River Coal Limited.* 89th Annual General Meeting of CIM, Toronto, Ontario, May 3-6.

Martin, D.C., P. Sheehan and D. Fawcett. 1985. *Geotechnical Assessment and Design of Optimum Method of Excavation of a Footwall Slope at Smoky River Coal Limited.* CIM Second District 5 Meeting, Hinton, Alberta.

[1] A Strategic Research Program project.

Deformation and Progressive Failure of Open-Pit Highwalls[2]

UNIVERSITY OF ALBERTA (N.R. MORGENSTERN), EDMONTON

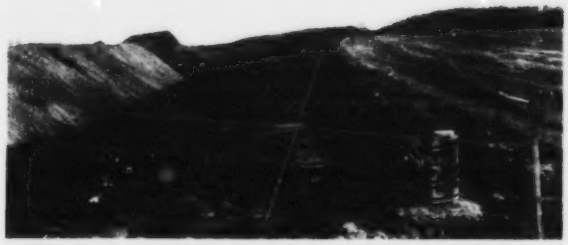
When a highwall fails in an open-pit mine, the falling debris can injure workers, damage mining equipment and cause costly delays. Some of these difficulties can be avoided or minimized if a method of predicting highwall failure can be developed.

In this project, under way since 1986, highwall deformation is being studied as mining progresses in an open pit at the Highvale mine.

Horizontal and vertical surface deformation is being measured using survey techniques that employ a series of tiltmeters installed in rows parallel to the highwall face. Piezometers are used to measure variations in the water table, and the strata comprising the highwall are being analysed for stress-strain properties. This will allow measured data to be used in a finite element numerical model of wall deformation processes.

This year, the deformation monitoring phase of the project was completed. Significant movement was detected in several shear zones. The instrumentation

[2] A Coal Research Grants Program project.



A survey monument for surface movements (foreground) and the top of an inclinometer (background), used to measure subsurface movement, are shown in this view of the highwall crest in Pit 03 at the Highvale Mine.

was able to detect the onset of highwall movement, the extent of movement behind the highwall crest and variations in the deformation mechanisms over a short distance. The data acquired to date are thought to be adequate to allow development of a numerical model.

Non-Cable Vehicle Guidance[1]

COAL MINING RESEARCH COMPANY, DEVON

The history of industrial development is rife with examples of automation having been adopted wherever technical and economic benefits could be realized. One of the more recent subjects of automation research is the development of automated vehicle guidance systems. Although some work has been done on guidance systems for equipment used in underground mining, little has been done to develop automated vehicles and equipment for surface mining.

Consequently, since surface mining is expected to predominate in Alberta for several decades, and every opportunity to reduce mining costs ought to be explored, a detailed review was made of non-cable vehicle guidance systems that might be used in Alberta's coal industry. They could represent an opportunity to manufacture new products and diversify Alberta's economy.

Some of the reviewed technologies included systems based on inertial guidance, dead reckoning, radar, laser beacons, ultrasonics, machine vision and radio frequencies. Those technologies that appear to have the greatest potential for use in Alberta coal mines employ radar, ultrasonics, lasers, dead reckoning and guidance algorithms.

The most promising systems were investigated in terms of range, accuracy, flexibility, reliability and costs. Plans were developed for constructing a single prototype and testing it under local mining conditions.

Experience gained from this project led to the development of an improved dragline monitor by the Coal Mining Research Company, and an automated machine control system for selectively mining coal adjacent to partings and waste material. The latter device, known as Automated Machine Control for Optimized Mining (AMCOM), is expected to help reduce the amount of coal lost, and the amount of foreign material introduced, when mining occurs at coal/waste interfaces.

Publication

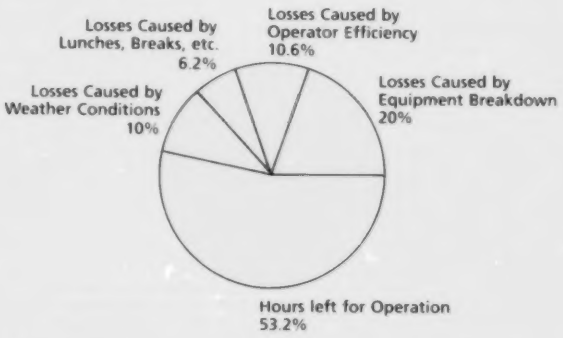
Coal Mining Research Company. 1987. *Non-Cable Vehicle Guidance: Phase I.* CMRC Report C08701.

[1] An Institutional Research Program project.

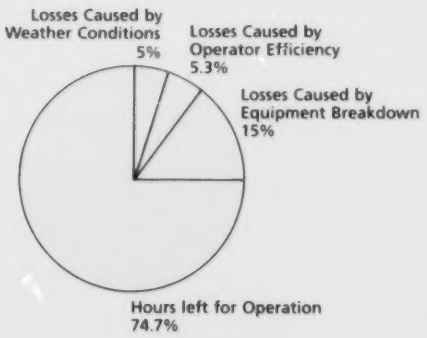
Theoretical Improvement in Machine Productivity with Automated Vehicle Guidance

Lost Time and Remaining Operational Time

A. Manual


Losses Caused by Lunches, Breaks, etc. 6.2%
Losses Caused by Operator Efficiency 10.6%
Losses Caused by Weather Conditions 10%
Losses Caused by Equipment Breakdown 20%
Hours left for Operation 53.2%

B. Automated


Losses Caused by Weather Conditions 5%
Losses Caused by Operator Efficiency 5.3%
Losses Caused by Equipment Breakdown 15%
Hours left for Operation 74.7%

Lasers in Coal Mining[1]

COAL MINING RESEARCH COMPANY, DEVON

This project is a component of CMRC's Innovative Mining Technology Program, which aims to encourage and facilitate the development, demonstration and application of innovative technologies suitable for surface and underground mining. The program evolved from CMRC's "Coal Mining in 2035" project, funded by the Office and completed in 1985/86.

In this project, potential uses for lasers in coal mining were examined. This is in keeping with the development and application of laser technology in a wide range of industrial situations.

As with most industries today, many day-to-day aspects of coal mining lend themselves to laser technology, but thus far lasers have been used only for land surveys and equipment positioning.

In this study, a review was made of potential laser applications, with specific reference to potential uses in coal mining. Included in the survey were discussions with laser researchers. The report concluded that available laser technology can be used in coal-mining environments for welding, surface treating, guidance, stability monitoring, data transmission and voice communication. The greatest potential is in equipment monitoring and control to improve the productivity of materials handling.

[1] An Institutional Research Program project.

Time-Dependent Behaviour of Coal Measure Rocks[2]

UNIVERSITY OF CALGARY (R. DAY), CALGARY

In planning underground coal mines in western Canada, it is important to be aware of the likely behaviour of soft rocks that commonly surround coal seams. For example, the roofs of mine shafts can sag, floors can heave and pillars can deform appreciably. Many of these changes are not accurately predicted by current methods.

In this project, initiated in 1986, computer simulations are being developed to predict the creep behaviour of rocks, coal and potash using data from simple, rapid testing of cores.

Last year, a coal mine simulation model was developed which could be run on a microcomputer. Meanwhile, an extensive data base of creep properties has been developed, allowing computer predictions of creep behaviour to be compared with actual results. These comparisons continued this year, with various refinements having been made to the model to obtain better correlations between predictions and laboratory data.

Laboratory tests to substantiate key aspects of the creep model are nearing completion.

[2] A Coal Research Grants Program project.

Geomechanics Technical Committee

In recent years, several research organizations, companies and funding agencies in Alberta have been involved in geomechanical studies of Alberta's resources, including coal, but these investigations have been carried out independently of each other. Therefore, in 1987/88, the Office convened a joint industry/government program development committee to provide advice about potential coal research projects in resource evaluation and mining. The program development committee comprised representatives of coal producers, engineering firms, geophysical instrument manufacturers, research and development agencies, and the Alberta and federal governments.

Subsequently, a technical committee was established. Its overall objective is to co-ordinate research and development funding among federal and provincial governments and private organizations in the area of coal production technology.

Three major research areas will be addressed by the committee. They are as follows:

Pre-Mining Hazard Identification;

Mining Techniques; and

Ground Stability Monitoring.

Also, the committee will co-ordinate mining technology components of research associated with reducing the delivered cost of western Canadian coal in Ontario.

Preparation and Upgrading

In a world coal market characterized by considerable competition, depressed prices and emerging coal-use technologies, consumers have become more demanding about product consistency in terms of combustion characteristics, ash production and the formation of air pollutants. To satisfy these demands, techniques for removing non-combustible mineral matter and moisture in coals are constantly being improved. This not only allows producers to supply higher quality coals, but also minimizes the costs of shipping non-combustible substances having no economic value.

Although washing continues to be the most common coal preparation method, in Alberta it generates substantial quantities of tailings formed from the clays and fines associated with Alberta coals. These tailings represent lost product and require large storage lagoons as an environmental protection measure. Therefore, alternatives to current washing techniques are needed.

As modern fuel standards have become more stringent in response to the availability of new or improved combustion technologies, coal researchers world-wide have begun to develop methods to upgrade coal into products from which most of the nitrogen and sulphur have been removed, or which have been energy-enhanced.

These types of investigations are being pursued in Alberta, particulary those aimed at upgrading bituminous and subbituminous coals to enhance their energy content and combustion performance characteristics, and to recover more fines in the form of economically valuable products.

Fifteen coal preparation and upgrading projects have been supported by the Office since 1984. The following section contains descriptions of nine that were active in 1987/88.

Washery Optimization[1]

COAL MINING RESEARCH COMPANY, DEVON

Largely because of their geologic setting, Alberta's mountain and foothills coals have been exposed to forces that cause them to be friable. This means that sizeable amounts of finely divided particles, called fines, are present in these coals. Fines are more difficult and more expensive to clean and recover than coarser coals, but they are present in sufficient quantities (up to 40 per cent of the product stream) to justify continual research efforts to minimize their loss and reduce preparation costs.

The Coal Mining Research Company has been conducting experiments aimed at meeting these objectives. In earlier projects, for example, studies were done to identify the difference between real coal losses in preparation plants, caused by feed fluctuations, and those which seem to be indicated by the commonly used sampling and analytical methods. In a continuation of that work last year, the suitability of standard tests to measure the performance of gravimetric coal separators used in Alberta coal preparation plants was evaluated. It was recommended that instead of generating partition curves from float/sink analysis, a technique involving discrete float/sink analysis to produce ash downgrade ratio curves should be used. In testing this technique with spiral separators, it was found that performance measurements could be made in half the time required for a standard partition curve performance test.

The tests also showed that spiral concentrators perform quite differently as feed conditions are varied, thus reinforcing the need to use performance tests that can be done more quickly and allow timely adjustments to be made to the separation equipment.

This year, attempts to optimize washery systems continued. Pilot-scale evaluations were made using a spiral separator unit and a two-stage, water-only, cyclone circuit to measure their performance under conditions of fluctuating feed. Samples of deslimed coal and refuse fines from a preparation plant were blended to form high- and low-ash feed components. The trials were completed and data analysis was in progress at year-end.

Results showed that deterioration of product quality occurred as feed fluctuations increased. The spiral separator clean coal quality varied with feed changes, whereas with the water-only cyclone there was an increased loss of coal to tailings.

Publications

McIntosh, P. and M.J. Kramer. 1986. *Washery Optimization: Literature Review of Performance Tests.* CMRC Report 8659-1.

Germain, R.J. and P. McIntosh. 1987. *Washery Optimization: Evaluation of Ash Downgrade Ratio Curves.* CMRC Report 8659-2.

[1] An Institutional Research Program project.

Froth Flotation Study at Coal Valley[1]

LUSCAR STERCO (1977) LTD., EDMONTON

Currently, Alberta producers of bituminous thermal coal discard the high ash fines portion during washing because of difficulties caused by the presence of colloidal clay. This reduces the yield and affects the overall ash content of the cleaned products.

Based on encouraging results from previous experiments, the University of British Columbia, the University of Alberta and the Coal Mining Research Company were subcontracted to study the flotation properties of three fine coal streams from the Coal Valley mine. The objective was to develop a process of economically producing a clean coal product having an ash content of 12 per cent.

The tests included evaluation of fines circuit losses and pilot-scale testing of conventional flotation technology and emerging column flotation techniques.

Experimental results were widely variable, making it difficult to draw any firm conclusions. It was estimated that a 12 per cent ash content could be achieved, but only at a 16 per cent yield. This is uneconomical.

Because of these results, it was decided not to proceed with larger-scale trials.

Publication

Latimer, R.C., D. Miller and R. Setton. 1988. *Froth Flotation Study: Final Report*. Luscar Sterco (1977) Ltd.

[1] A Strategic Research Program project.

Moisture and Ash On-Stream Analyser[2]

COAL MINING RESEARCH COMPANY, DEVON

As coal customers become more demanding about product consistency, coal producers are obliged to improve their quality control methods. One way to achieve this is to use on-stream moisture and ash monitors in preparation plants. While numerous coal producers in Australia and the United States are now using these instruments, Canadian coal producers have not begun to use them routinely, partly because of doubts about their accuracy.

In this project, information on commercially available and recently developed on-line instruments, as well as any available results of field trials, were obtained and assessed in terms of potential suitability for western Canadian coals.

It was found that three commercially available analysers might be useful in western Canadian coal preparation plants, but none is accurate enough to be used with low-rank coals. This represents a development opportunity. Because several coal companies were interested in learning about the current technology, a one-day seminar, "Coal Moisture and Ash On-Line Analysers," was held at the Coal Research Centre, Devon. There were 75 attendees, some of whom were willing to become involved in field trials of three types of analysers.

[2] An Institutional Research Program project.

Recovery of Coal from Tailings[3]

COAL MINING RESEARCH COMPANY, DEVON

Coals originating in the mountains and foothills regions of Alberta produce substantial quantities of fines when they are mined and washed; they contain up to twice as much as those from some coal regions of the world. While some of these fines remain with product-quality coal, others become "tailings" that currently have no commercial value despite having a significant energy content. They are stored in holding ponds which become increasingly larger the longer a coal mine is in operation.

In this project, the objective is to determine whether or not it is economically feasible to do the following: salvage fine coal from processing plant tailings; dewater and dispose of unusable refuse in an environmentally acceptable manner; and make more efficient use of the water employed in coal washing. While minimizing environmental problems was one of the principal concerns of this study, economics remain the key issue.

The study found that coal fines entrained in tailings are in two size fractions: (1) 0.6 mm x 0.2 mm, and (2) -0.2 mm. A review of fine coal recovery technology suggested that spiral concentrators can be used to reclaim the larger particles, while new developments in flotation should be capable of improving the recovery of smaller particles. However, these developments must be refined before they can be considered for use locally.

While this suggests that fines recovery may be possible, there is little economic incentive to go ahead with it. An increased proportion of fines would be unacceptable to many coal purchasers because fines are dusty and difficult to handle. It was concluded that a viable coal agglomeration or

[3] An Institutional Research Program project.

pelletization method must be developed before increased coal fines recovery will become economic.

Tailings dewatering technology was also reviewed. While improvements in techniques continue to be made, the holding pond alternative remains the least costly. It was stated that holding pond designs allowing better management of process water are needed.

Preparation and Upgrading Assistance[1]

COAL MINING RESEARCH COMPANY, DEVON

A staff engineer was seconded to the Alberta Office of Coal Research and Technology to provide technical assistance in two high-priority areas of coal research. He participated in developing strategies to reduce the delivered cost of Alberta coal in Ontario. As well, he identified aspects of coal preparation and upgrading which should be developed to produce coals that satisfy the requirements of advanced combustion processes.

[1] An Institutional Research Program project.

Fine Coal Cleaning Technical Committee

In recognition of the problems caused by coal fines and a number of concurrent, but independent, research projects under way to deal with fines, it was concluded that it might be appropriate to establish a Fine Coal Cleaning Technical Committee to better co-ordinate and fund research efforts. This was given impetus by the report of the Intergovernmental Secretariat to the Action Committee on Western Canadian Low Sulphur Coal to Ontario which recommended that Alberta should take the lead role in initiating research on fine coal cleaning. Consequently, a technical committee[2] was established.

It is anticipated that work will commence on projects in 1988/89.

[2] *Individual participants were:* Crow's Nest Resources Ltd., Obed Mountain Coal Company Limited, Gulf Canada Corporation, Fording Coal Limited, Luscar Sterco (1977) Ltd., Westar Mining Ltd., Luscar Ltd., Canada Centre for Mineral and Energy Technology, and Alberta Office of Coal Research and Technology assisted by the Coal Mining Research Company.

Fine Coal Technical Assistance[3]

COAL MINING RESEARCH COMPANY, DEVON

The services of a staff engineer of the Coal Mining Research Company were funded by the Office to provide secretariat support to the Fine Coal Cleaning Technical Committee and technical advice to both the Committee and the Office.

[3] An Institutional Research Program project.

Coal Beneficiation Process[4]

GULF CANADA RESOURCES LIMITED AND UNOCAL CANADA, CALGARY

In an earlier phase of this project, a process was developed to upgrade the energy content of low-rank coals and make them suitable for shipping. This was done by treating the coal with a low-cost, residual petroleum product derived from heavy oils and bitumen. This leaves a coating on each dried coal particle, reducing coal dust and improving the coal-handling properties. Last year, a pilot plant located at the Obed Mountain Coal Company mine was used to produce beneficiated coal at production rates of up to 100 tonnes an hour. When the coal was stockpiled, however, it experienced autogenous heating. Subsequent investigation revealed that this storage instability was apparently caused by large differences in equilibrium and residual moisture levels. Laboratory evaluations of moisture and oxygen sorption confirmed that the upgraded product is more reactive than the parent coal and a stabilizing process or agent would be needed to make the process commercially viable.

This year, optimized process conditions were established to satisfy a set of 96-hour heating and oxygen adsorption criteria. Bench-scale mixing equipment was modified to allow increased residence time, product cooling, improved feed capacity and installation of monitoring equipment. Two tonnes of beneficiated product were stockpiled and tested for stability. It was found that the treated product was as stable as the untreated coal sold by Obed.

[4] A Strategic Research Program project.

Coal Agglomeration Process Development[1]

ALBERTA RESEARCH COUNCIL, DEVON

For the past five years, researchers at the Alberta Research Council, with initial funding from the Office and subsequent funding from the Electric Power Research Institute and other sources, have been developing a method for upgrading low-rank coal, involving a process called oil agglomeration. By mixing heavy oil or bitumen with coal slurries under controlled conditions, large particles called agglomerates are formed from which much of the undesirable mineral matter present in the original coal has been removed and transferred to the water. This results in products having a higher energy content and lower ash than the parent coals from which they are derived. Subsequent combustion testing showed that agglomerates formed from subbituminous coals displayed excellent combustion characteristics. These results demonstrated that oil agglomeration is a promising upgrading method.

This year, a consortium[2] of 22 companies and institutions provided funding for a pilot-scale evaluation of the process. A continuous 6-tonne-a-day (250 kg/hour) pilot plant was built and a continuous oil recovery unit was designed. This equipment will be used to evaluate the agglomeration potential of coal samples provided by members of the consortium, and provide data to be used in calculating the process economics of a commercial-scale plant.

Results of preliminary analyses on three Alberta subbituminous coals are as follows:

(The evolution of Alberta Research Council's coal agglomeration technology is described in the Office publication *Development of an Agglomeration Process to Beneficiate and Transport Alberta Coals*. Single copies are available from the Alberta Energy/Forestry, Lands and Wildlife Information Centres; see page 62)

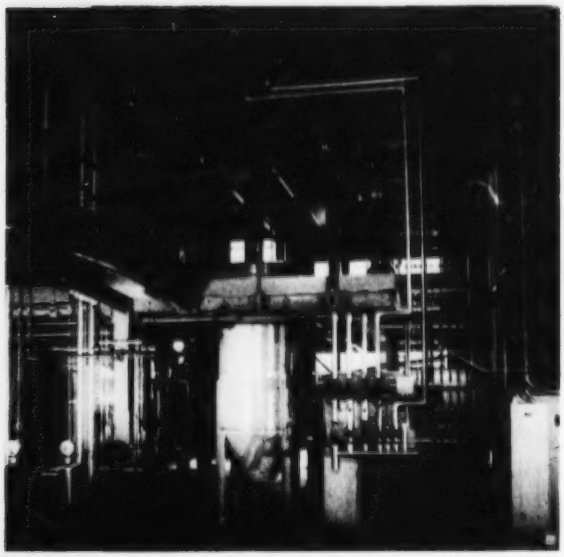
[1] An Institutional Research Program project

[2] Including the Electric Power Research Institute, American utility companies, state and federal governments, Canadian oil firms, coal companies, provincial governments, utility companies and the Alberta Office of Coal Research and Technology.

Beneficiation of Subbituminous Coals by Agflotherm[3] Process

	Sample	Moisture [%]	Ash [%]	Calorific Value [BTU/lb]	Oil Recovery [%]	
Coal	A					
	Parent Coal	16.3	24.6	7 840	–	
	De-Oiled Agglomerates	4.1	9.7	11 580	44.4	350°C
					92.9	420°C
Coal	B					
	Parent Coal	16.1	23.1	8 040	–	
	De-Oiled Agglomerates	3.9	9.4	11 730	42.6	350°C
					74.1	410°C
Coal	C					
	Parent Coal	9.3	14.3	10 070	–	
	De-Oiled Agglomerates	2.5	12.4	11 820	50.9	350°C
					62.2	390°C

[3] Agglomeration with heavy oil followed by thermal treatment.



Researchers at the Alberta Research Council are using the pilot plant shown here to continue their development of a coal-upgrading process based on oil agglomeration.

Agglomeration of Coking Coal[1]

SMOKY RIVER COAL LIMITED, GRANDE CACHE

Metallurgical coal currently being mined at Smoky River Coal Limited contains 40 per cent fines, and coals expected to be mined in the future have a fines content as high as 50 per cent. While froth flotation is being used to recover some of the fines, the process is often overloaded. The recovered product is also too dusty and difficult to handle and therefore cannot be sold for premium prices.

Last year, with funding assistance from Energy, Mines and Resources Canada and the Industrial Research Assistance Program (IRAP), the company experimented with an oil agglomeration process (developed by the National Research Council) as a fines-recovery method. It was found in laboratory tests that recovery rates were higher than for froth flotation, and the product appeared improved sufficiently to allow it to be sold as metallurgical coal.

The company and the National Research Council (NRC) decided to evaluate the potential of the NRC oil agglomeration process using the NRC mobile pilot plant at the mine site. The Office agreed to participate in the project by sharing the costs to evaluate the quality of the oil-agglomerated product. Additional support was provided by Energy, Mines and Resources Canada/Canada Centre for Mineral and Energy Technology.

Two different coal feeds were evaluated in these tests. One was the -100 mesh raw coal feed to the existing flotation circuit which comprises approximately 18 per cent of total plant feed. The second was the -28 mesh thickener underflow containing typically 40 per cent ash.

Both coal feeds were successfully agglomerated and separated from the ash and excess water. Preliminary product evaluation indicated acceptable coking, handling and dustiness characteristics for the -100 mesh raw coal feed. The agglomerated coal from the thickener underflow could not be used as a coking coal but should make a satisfactory thermal coal product.

Drying and blending -100 mesh coal agglomerates with the balance of clean coal has a major effect on the handling and dustiness characteristics of such coal. Process economics indicate that capital and operating costs associated with agglomeration are higher than for expanding the current flotation circuit, but these higher costs are largely offset by the higher yields associated with agglomeration. If the capital costs of an agglomeration facility and the quantity of oil required to achieve agglomeration can be reduced by 25 per cent and 50 per cent respectively, then major economic benefits can be realized.

The use of spirals to treat the -28 + 100 mesh raw coal feed was examined. Preliminary results indicated that a satisfactory product can be produced, but with a somewhat lower yield than with the existing flotation circuit.

The potential to improve the size consist of the agglomerated coal by conventional pelletizers was also demonstrated, but with some reduction in coking characteristics.

[1] A Strategic Research Program project.

Combustion

Some emerging coal combustion technologies achieve optimum performance from coals having narrowly specified properties. Consequently, coal producers who wish to sell coal to the users of these technologies must be prepared to provide detailed information about the combustion characteristics of their coals. This also implies that coal producers should know how a coal will perform before it is removed from the ground. Therefore, developments in combustion technology have a direct bearing on coal exploration, mining and upgrading. Furthermore, advances in the science of coal combustion make it necessary to test coals for properties other than those revealed by ultimate and proximate analyses. This means new or improved laboratory-scale combustion testing methods must be developed that not only simulate coal burning in thermal plants but, ideally, can minimize the need for the expensive, full-scale combustion tests used in the past.

Another important function of coal combustion research is to encourage coal producers, coal users and manufacturers of coal-burning equipment to become jointly involved in projects. This can lead to knowledge sharing and the enhancement of technology development in ways that benefit all parties.

With these issues in mind, the Office has supported 12 coal combustion research projects, seven of which were active in 1987/88 and are described in the following section.

Coal Combustion Research Program Development

Since late 1985, most coal combustion research projects funded by the Office have resulted from deliberations and recommendations of the Joint Industry/Government Coal Combustion Research Program Development Committee. This group comprised coal mining companies, Canadian boiler manufacturers, electric utility companies and the Alberta Office of Coal Research and Technology, assisted by the Coal and Hydrocarbon Processing Department of the Alberta Research Council.

The Coal Combustion Research Program was established to develop and demonstrate combustion technologies in which western Canadian coals can be used to their best advantage. It was motivated by:

- predictions and indications that thermal coal consumption will increase significantly world-wide; however, the international coal market is highly competitive;
- predictions that domestic coal consumption will increase, too.
- recognition of the fact that coal quality will be an increasingly important criterion for coal selection in both domestic and international markets; and
- belief in the idea that a co-ordinated coal combustion research and development program could help the coal industry remain abreast of the latest developments in combustion technology, and provide a strategy for testing the suitability of western Canadian coals in these new technologies.

It was further believed that such a program could provide the organizational structure for evaluating new or improved combustion technologies and their ability to reduce the environmental effects of coal combustion. Also, this approach could identify and research expanded uses for coal and enhance market opportunities in Canada and abroad.

Discussions among the various participants in the program led to an agreement on the need for several major research projects. These would be managed by technical committees comprising co-chairmen from industry and government, and involve appropriate representatives from contributing organizations.

Included among the recommended research projects were the following:

Coal Gasification Study;

Dry Sorbent Injection Study; and

Coal Utilization for Enhanced Oil Recovery Project.

Each of these has evolved into a major program managed by individual technical committees. Meanwhile, the Joint Industry/Government Coal Combustion Research Program Development Committee was disbanded in 1987.

Prediction of Coal Combustibility[1]

ESSO RESOURCES CANADA LIMITED, CALGARY

The identification and development of commercially valuable coal deposits would be assisted by an ability to determine combustion characteristics from core hole samples rather than from expensive burn tests that require large quantities of coal. Furthermore, the methods currently used to estimate the combustion behaviour of coals can be misleading. Therefore, this project, which began in 1985, is attempting to show that combustion characteristics can be predicted more quickly and accurately, and less expensively using an alternative to the current geological method of classifying coals.

While boiler systems are designed to handle coals possessing various amounts of combustible material (as indicated by volatile matter measurements), it is known that coals containing similar amounts of volatile matter can behave very differently in combustion tests.

This behaviour is now thought to be caused by different assemblages of substances known as macerals. These are discrete, organic, microscopically identifiable particles, of which there are several types, each having its own characteristic properties. Thus, volatile matter can be thought of as a measure of the sum of the properties of all the component macerals.

The problem with this situation is that coals having similar amounts of volatile matter can have very different amounts of individual macerals. This is thought to be the reason for variable combustion performance.

Therefore, in this study, the concentration of the vitrinite maceral was measured and compared with its combustion performance to determine whether a more reliable method could be developed to predict combustion behaviour.

During the first year of the study, 13 vitrinite concentrates derived from coal were tested for thermal reactivity by pyrolysis at 1300°C and combustion at 900°C. The vitrinite concentrations of each sample were determined by measuring reflectance with a microscope. Good correlations were established between thermal reactivity and reflectance characteristics, allowing the researchers to make predictions about the combustion behaviour of four test coals. Subsequent testing revealed that these predictions were accurate approximately 75 per cent of the time. This supported the initial hypothesis that coal rank and maceral composition influence combustion behaviour, at least at the laboratory scale.

The results of ignition tests and reflectance microscopy investigations (shown here) have demonstrated that correlations exist between the geochemistry of coal and combustion characteristics.

During the second year, the predictive procedure was applied to a wider range of coals, including bituminous and subbituminous coals.

The predicted char values for combustion at 900°C were derived from feed coal reflectograms and compared to actual char values resulting from combustion testing. Good agreement was found between predicted and measured results, and the technique was found to be superior to the use of volatile matter measurements when predicting the combustion behaviour of coals containing more than 25 per cent of the inertinite maceral. Thus, the technique is especially promising for lower-rank western Canadian coals.

A planned attempt to relate reflectance measurements to full-scale test burn information was abandoned because insufficient public domain test burn data were available. However, it was concluded that vitrinite optical reflectance represents a potentially useful technique which, with further development, might be suitable for in situ mapping of coal combustibility through downhole or surface geophysical methods.

While no further work on this project is planned, the Office encourages other researchers to make use of the findings from this investigation.

[1] A Strategic Research Program project.

International Energy Agency Coal Combustion Science[1]

NETHERLANDS ENERGY RESEARCH FOUNDATION, PETTEN

Annex II of the International Energy Agency Combustion Science Research Program involves fundamental studies and a series of investigations using semi-industrial scale coal burners to advance the science of pulverized coal combustion and minimize adverse environmental effects. Facilities of the International Flame Research Foundation at IJmuiden, The Netherlands, are being used. The principal objective is to design burners capable of using a wide range of coals to produce flames having acceptable combustion characteristics, while generating few atmospheric pollutants.

The Annex II studies are jointly funded by Canada, The Netherlands and the Federal Republic of Germany. Since 1985, the Canadian contribution has been divided among the Canada Centre for Mineral and Energy Technology (CANMET), the Canadian Electrical Association and the Alberta Office of Coal Research and Technology. The Office is participating on behalf of Alberta coal producers to obtain comparative information on the combustion performance of selected Alberta coals relative to other internationally traded coals. A second objective is to acquire knowledge about the use of low-rank Alberta coals for power generation and other applications.

The research program is investigating the following mechanisms: nitrogen oxides (NOx) formation during pulverized coal combustion and opportunities for their reduction through staged combustion; sulphur oxides (SOx) formation and reduction by the use of direct sorbent injection; transformation of mineral matter during combustion in relation to combustion system slagging, fouling and fly ash emissions; and combustion of various types of coal from several sources. The study is also developing methods of predicting flame characteristics.

This year, a proprietary aerodynamically air-staged burner, which can be retrofitted in wall-fired boilers and is designed to reduce the production of nitrogen oxides, was used to study the behaviour of three ranks of coal. Bituminous thermal coal from the Coal Valley mine was included in this study. The investigation showed that coal type strongly affects the level of NOx emissions and the degree to which emission reduction can be achieved in a burner of this size.

It was found that, ideally, a coal should release most of its nitrogen with the volatiles and form a reactive char for good carbon burnout. The temperature distribution within the furnace also affects NOx levels, implying that NOx reduction may be greater for larger burners.

A literature review and a screening study of fuel staging were completed. Coal from the Obed Mountain mine was included in this investigation. Also, numerical modelling of combustion swirling flows was completed. Other aspects of this research program are scheduled for completion in 1988/89. A three-year extension to the current research agreement is under discussion, with emphasis on fuel-staging studies for additional NOx reduction.

[1] A Strategic Research Program project.

Combustion Program Planning[2]

ALBERTA RESEARCH COUNCIL, DEVON

Since 1985, research officers from the Alberta Research Council have been providing technical support to the Office to help develop the Joint Industry/Government Coal Combustion Research Program and to participate on technical committees related to the International Energy Agency (IEA) Combustion Science Research Program, Annex I and II.

Because coal combustion phenomena are complex, the IEA Annex I Combustion Science Research Program was established to increase international collaboration in fundamental coal combustion research. This collaboration involves the exchange of research results in an attempt to increase international communication and prevent duplication of effort. Although no formal co-operative projects have yet been established, attendance at committee meetings has helped Alberta researchers become aware of coal research programs in other countries.

The Annex II program is a jointly funded research program, with funding from Canada, The Netherlands and the Federal Republic of Germany. The objective is to carry out research at the International Flame Research Foundation to minimize the environmental effects resulting from the combustion of a variety of coals.

Technical advice provided in previous years contributed to the implementation of major research programs on coal use for enhanced oil recovery and the development of coal gasification technology.

This year, several coal-fired pilot plants and power stations in the Federal Republic of Germany were visited and discussions were held regarding potential

[2] An Institutional Research Program project.

co-operative research programs. Based on the good combustion properties demonstrated by highly reactive Alberta coals at the International Flame Research Foundation, it is apparent that Europeans are becoming more aware of Alberta coals and their potential use in new combustion technologies to reduce SOx and NOx emissions. This is an important consideration in many European countries where allowable emission levels are low and enforcement of emission regulations is strict.

The presence of Alberta Research Council representatives at the Annex II Executive Committee meetings ensured that the research program addressed Alberta's interests. Several Alberta coals were included in the burner testing and coal characterization studies. Also, a technical briefing on research studies performed under Annex II at the International Flame Research Foundation was organized in Edmonton for representatives of the Alberta coal industry, the universities and the Alberta Research Council.

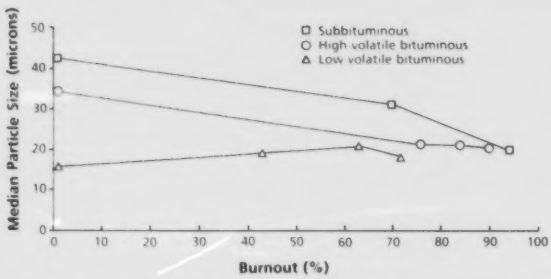
Influence of Porosity on Combustion[1]

ALBERTA RESEARCH COUNCIL, DEVON

In a previous study carried out at the Alberta Research Council and aimed at developing a better understanding of coal combustion mechanics, the combustion behaviour of partially burnt coals (hydropyrolysis chars) was found to be related to the surface area and pore volume in the char particle macropores (pore diameter greater than 180 Å). This suggested that porosity was controlling the particle reaction rates. Consequently, an analytical technique was developed to characterize the surface area and pore volume distribution of chars. These measurements were used to predict combustion rates in an entrained flow combustor (EFC), as well as explain discrepancies between reaction rates measured by EFC and thermogravimetric analysis (TGA).

To further develop the potential of this analytical tool and provide more information for a mathematical model describing the relationship between char porosity and combustion behaviour, an investigation was undertaken this year on a range of coal types.

Median Particle Size of Laminar Flow Combustor Chars



Three coals were burned in a 3 kg/h laminar flow combustor. Highvale subbituminous and Coal Valley high volatile bituminous coals were very reactive. They burned near the entrance to the combustor and attained carbon burnout in excess of 90 per cent. Smoky River low volatile bituminous coal was not as reactive; the coal burned near the exit of the combustor.

Analysis of the partially burnt chars showed that Highvale and Coal Valley coals burned with decreasing size, while Smoky River coal swelled slightly and burned at approximately a constant size. All coals displayed a significant increase in surface area, from ~ 5 m^2/g for a raw coal to over 150 m^2/g at 50 per cent burnout. The surface area attained a maximum size, then decreased with burnout. The decrease was more significant with Smoky River coal (23 m^2/g at 70 per cent burnout) compared with Coal Valley coal (55 m^2/g) and Highvale coal (150 m^2/g). Porosity and open pore volume were also less for Smoky River coal.

Mercury porosimetry showed that while the Smoky River coal has significant pore volume, it does not change as much during combustion as the Highvale or Coal Valley chars, both of which showed large increases. This technique, however, was subject to large variances, indicating a need to use another technique such as scanning electron microscopy.

[1] An Institutional Research Program project.

Combustibility of Upgraded Alberta Coals[1]

ALBERTA RESEARCH COUNCIL, DEVON

Several research projects supported by the Office have demonstrated that Alberta coals can be upgraded by a variety of processes. These range from relatively simple techniques that remove some moisture, to more complex procedures, such as agglomeration, which lower both the moisture and mineral contents of coal and supplement the energy content.

While conventional analysis and testing of these upgraded coals indicate that they are improved relative to their parent coals, little is known about their combustion behaviour.

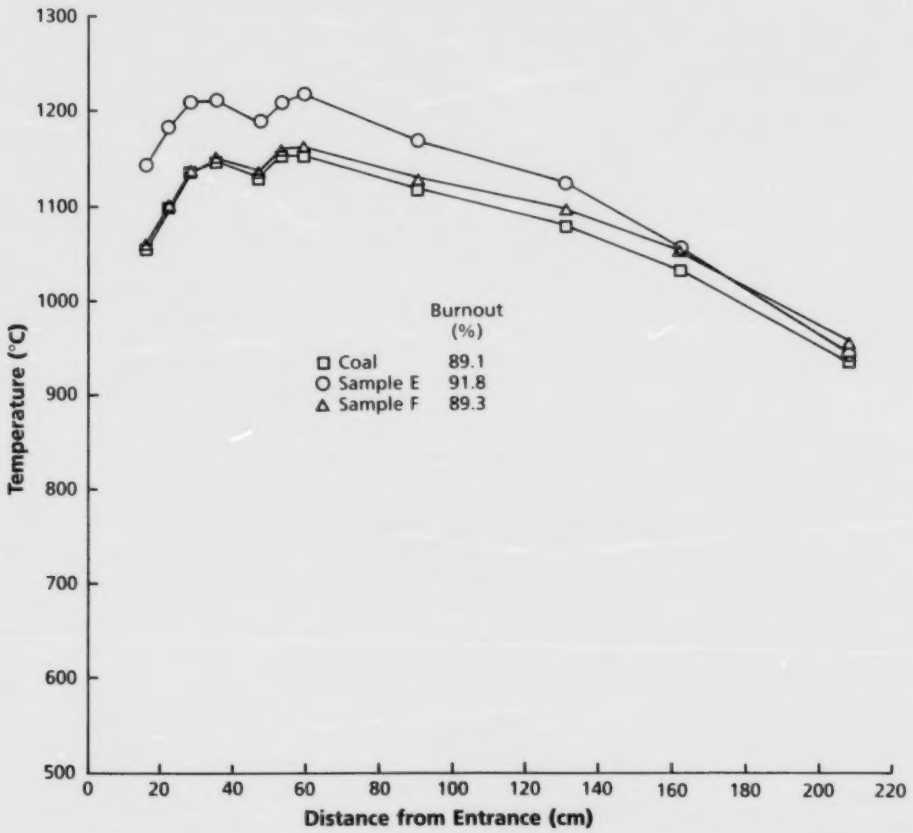
Consequently, in this project, a low-rank coal upgraded by the Gulf Canada process (described elsewhere) and the parent coal were tested to determine their relative combustion performance.

Four upgraded coal samples, prepared at different process conditions, and the parent coal were tested using thermogravimetric analysis and entrained flow combustion tests to investigate how varying process conditions affected combustion performance. Thermogravimetric tests indicated that all samples had similar ignition and combustion completion temperatures, although the burnout profiles were different. In the entrained flow combustion tests, some of the treated samples showed lower combustion reactivity than the parent coal. Some samples, however, were as reactive as the parent coal.

Further combustion tests were performed at a larger scale on the laminar flow combustor. This unit fired 3 kg/h of pulverized sample in a self-sustaining flame. Two samples, produced at promising upgrading conditions, and the parent coal were tested. Both of the treated samples gave combustor temperature profiles and per cent carbon burnouts similar to those of the parent coal. These preliminary results indicate that the combustion properties of the upgraded coal were similar to those of the parent coal.

[1] An Institutional Research Program project

Combustor Wall Temperature Profile for Upgraded Coal



Evaluation of Blending on Combustibility[1]

ALBERTA RESEARCH COUNCIL, DEVON

High volatile bituminous coals from the foothills region of Alberta are extremely reactive and can be burned in a wide range of boilers, but they are somewhat low in calorific value for coals that must be transported long distances to markets. Conversely, low volatile bituminous coals used for metallurgical purposes have a high calorific value, but a low combustion reactivity. Therefore, it has been reasoned that the reactivity of the low-volatile bituminous coals and the calorific value of the high-volatile coals might be increased by blending the two. This might allow Alberta coal producers to offer new products which are able to satisfy customer specifications in a way that could not be met by either parent coal.

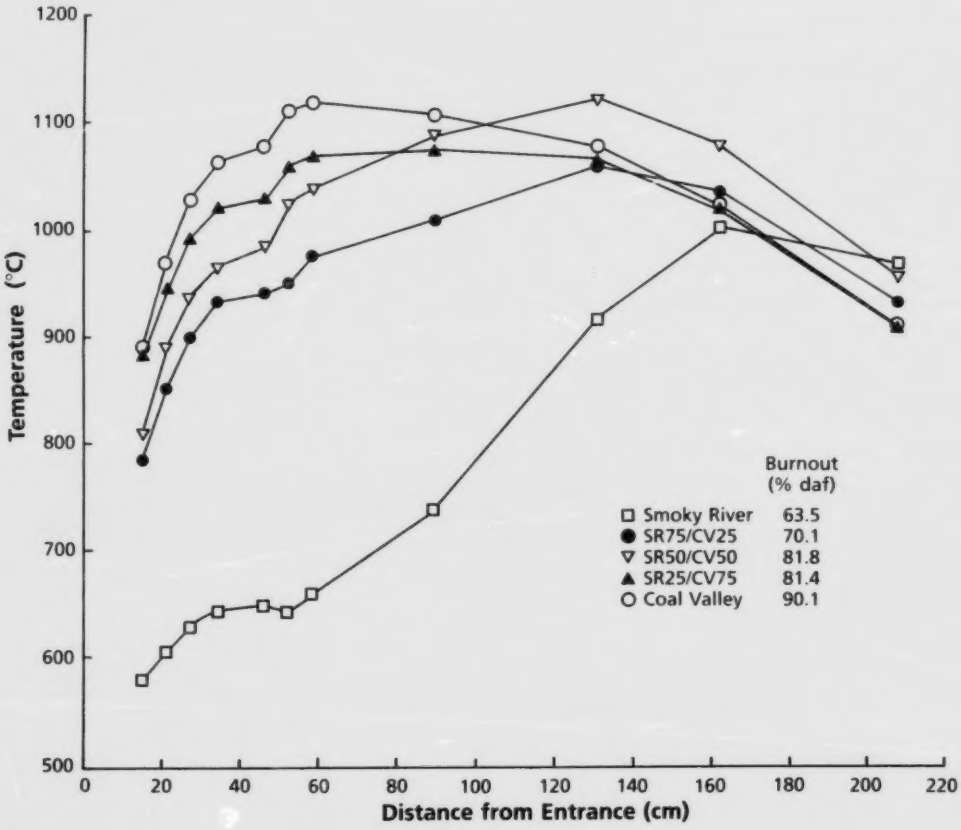
To determine the effects of blending on combustion characteristics, flame stability and carbon burnout tests were performed on 25:75, 50:50 and 75:25 blends of low-volatile (Smoky River) and high-volatile (Coal Valley) bituminous coals, as well as the individual parent coals. Testing was done using entrained flow combustion, thermogravimetric analysis (TGA) and laminar flow combustion.

Results from the entrained flow combustion tests showed that carbon burnout was equal to a simple arithmetic addition of the results from the two parent coals. However, interactions were more complex in the laminar flow combustor, which has a self-sustaining flame. Coal Valley coal ignited and burned in the first half of the combustor, while Smoky River coal was mostly consumed in the second half.

Wall temperature profiles and carbon burnouts of the blends were intermediate to those of the parent coals. However, the 50:50 blend showed a positive interaction of the coals, having the high initial temperature of the Coal Valley coal and the combustion characteristics of the Smoky River coal in the latter stages of combustion. These two factors contributed to a higher-than-expected carbon burnout.

[1] An Institutional Research Program project.

Laminar Flow Combustor Wall Temperature Profiles for Coals and Blends



Causes of Spontaneous Combustion of Western Canadian Coals[1]

UNIVERSITY OF CALGARY (F.W. BACHELOR), CALGARY

While the ability of coal to burn readily in the presence of oxygen and an ignition source is the primary reason it is a highly desirable fuel, an undesirable characteristic of coal is its tendency to ignite while it is stored in stockpiles or is in transit from mine to market.

Although researchers have been attempting to explain the process of spontaneous combustion for years, little is known about the mechanism. It is generally believed, however, that moisture must be present and oxygen is adsorbed onto fresh coal surfaces but, as yet, no one knows how spontaneous combustion is initiated or sustained.

Since 1986, this investigation has been focusing on three possible mediators of the spontaneous combustion reaction. They are: trace metals, free radicals, and the exinite maceral.

This work has concentrated on one western Canadian high volatile bituminous coal known to be susceptible to spontaneous combustion. It was subjected to proximate, ultimate and petrographic analysis and was also analysed for trace metals. The as-received coal, as well as a portion which had been washed to remove most of the minerals, and other samples to which manganese or cobalt had been added, were subjected to moist air treatment. They were then analysed by electron spin resonance spectroscopy (ESR) for changes in peroxides and free radicals on fresh coal surfaces.

Another sample, enriched to 15 per cent exinite, was given the same treatment and analysis.

It was found that changes in the trace metal content did not cause any significant temperature changes within the coal, although the ESR results did show that trace metals altered the peroxide/free radical concentrations. Maceral enrichment apparently caused no detectable difference in ESR analysis results.

It was concluded that no substantial evidence could be found for the hypothesis that any of these three substances plays a major role in spontaneous combustion.

[1] A Coal Research Grants Program project.

Spontaneous Combustion Technical Committee

On November 13, 1987, the Office sponsored a one-day symposium on the spontaneous combustion of coal. Three of the six speakers were from Australia, France and the United States. They described current research in their respective countries, while the other speakers described recent developments in Canada.

Based on findings presented at the symposium, it was decided that more research should be carried out in Alberta. Consequently, a Spontaneous Combustion Technical Committee[2] was formed. Three objectives pertaining to cleaned coal were accepted by the committee members. They were:

- establish thermal stability criteria;
- establish a stability-monitoring protocol; and
- establish a method of predicting stockpile behaviour over time.

Projects related to these objectives are expected to be initiated in 1988/89.

[2] *Initial participants were:* Obed Mountain Coal Company Limited, Gulf Canada Resources Ltd. and the Alberta Office of Coal Research and Technology, assisted by the Alberta Research Council and the Coal Mining Research Company. The Canada Centre for Mineral and Energy Technology also participated in the work of the Committee.

Liquefaction

During the next 30 years, production of conventional crude oil from Alberta's established oil fields is expected to decline well below current levels. The rate of decline will depend on a number of factors, such as world oil prices and demand, but eventually it will become necessary to produce more synthetic crude oil from Alberta's oil sands, heavy oil and coal. Although the economics of producing oil in this manner are unattractive at present because of depressed oil prices, abundant quantities of raw materials are readily available within Alberta. For instance, Alberta's proven reserves of subbituminous coals could provide enough synthetic crude oil to satisfy domestic consumption for at least the next century, assuming a suitable and economic liquefaction process can be developed to convert coal to petroleum substitutes.

One conversion concept that is showing some promise, and has been studied extensively in Alberta, involves co-processing of coal and heavy oil or bitumen. This process not only provides a method of producing synthetic crude oil from coal, but may also prove to be useful in upgrading heavy oil. This and other potential liquefaction processes are under development, some of which may involve less severe reaction conditions than used elsewhere. Also, methods of analysing the quality of liquefaction products are being actively investigated in Alberta. Furthermore, the level of liquefaction research in Alberta has led to considerable collaboration among the various participants at Alberta Research Council, the University of Alberta and in private industry.

So far, the Office has supported 17 coal liquefaction research projects, some of which are multi-year, major efforts. Eight projects, active this past year, are described in the following section.

PYROSOL Process Development[1]

CANADIAN ENERGY DEVELOPMENTS INC., EDMONTON

The synthetic crude oil needed to replace conventional crude oil can be produced by upgrading bitumen or heavy oil, or by the simultaneous upgrading of coal and heavy oil/bitumen. The latter is known as co-processing. For several years, it has been the subject of extensive studies by Canadian Energy Developments Inc. (formerly CCLC Technologies Inc). The overall objective of this company is the design, construction and operation of a commercial-scale co-processing upgrader in Alberta in the 1990s.

Currently, the company is simultaneously developing two co-processing schemes. One of these, known as PYROSOL, is a low-severity, two-stage catalytic hydrogenation process. It comprises mild hydrogenation and coking in a pressurized delayed coker under a hydrogen atmosphere.

The synthetic crude product from the PYROSOL Process contains approximately 10 per cent naphtha, 60 per cent middle distillate and 30 per cent heavy distillate. It has the potential to be a premium product because it contains substantial quantities of middle distillate from which aviation and diesel fuels are made.

The second co-processing scheme, the CCLC Process, involves coal solvolysis in a heavy oil slurrying medium followed by moderate severity hydrogenation of the solubilized coal and heavy oil.

The synthetic crude from the CCLC Process is a light distillate containing approximately 35 per cent naphtha, 45 per cent middle distillate and 20 per cent heavy distillate. The product is similar to that currently produced by the oil sands plants in Fort McMurray.

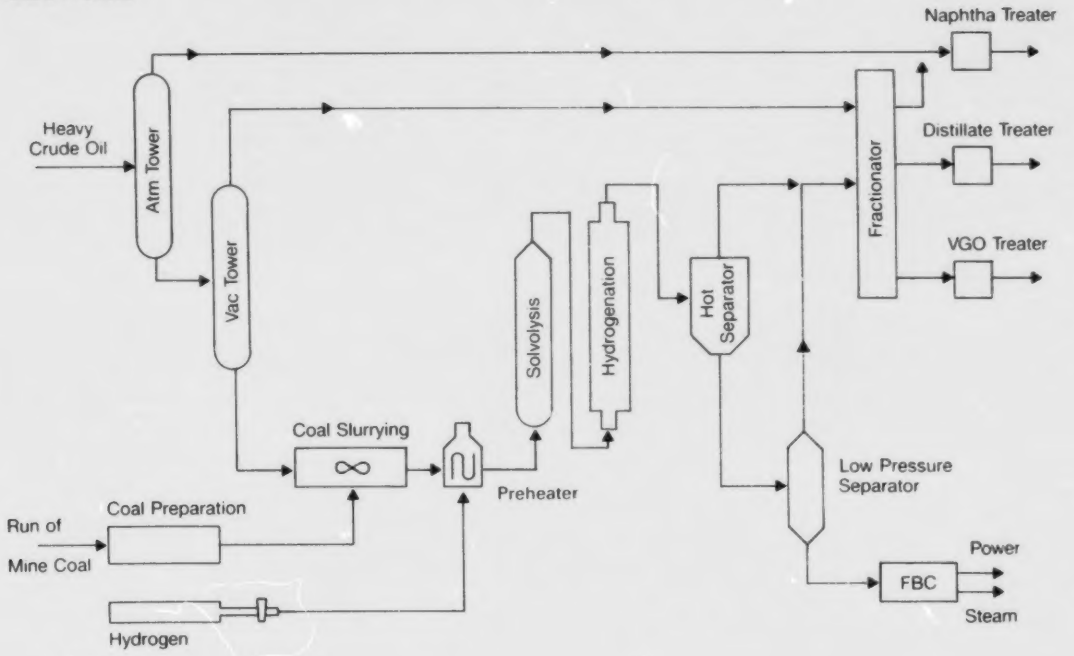
Interest in these processes, and co-processing in general, stems from the fact that use of low-cost coal lowers the feedstock cost and the overall production costs of these upgrading schemes versus upgrading of heavy oil or bitumen alone.

Since this process development project began in 1986, a 2 kg/h two-stage hydrogenation bench-scale unit (BSU) and a 1.3-litre pressurized delayed hydrocoker have been used to conduct hydrogenation severity studies. In these studies, hydrogenation pressure, temperature and reactor residence time were varied to control the distillable oil yield and maintain a high level of pitch conversion. Experiments of this type continued this year, with encouraging production of distillable oils averaging approximately 70 weight per cent of the total feed (daf-basis). Studies such as these, aimed at optimizing the process and product quality, will continue next year, along with supporting investigations of the PYROSOL Process in the Federal Republic of Germany by Gesellschaft für Kohleverflüssigung mbH (GfK), the originators of this particular scheme.

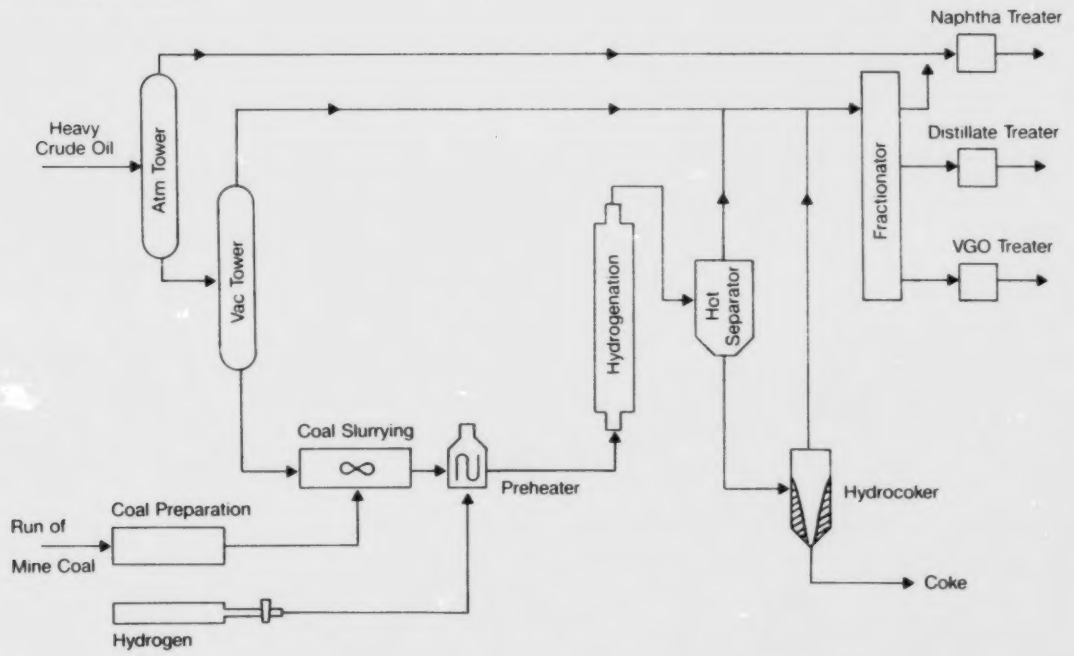
This year, a 227 kg (¼ ton) per day continuous process demonstration unit (PDU) was commissioned by Canadian Energy Developments Inc. to allow long duration, continuous studies to be made on a larger scale.

[1] A Strategic Research Program project.

CCLC Process



PYROSOL Process



Coal Research Workshop and Symposium

On November 12, 1987, the Alberta Office of Coal Research and Technology sponsored a coal research workshop, which was held at the University of Calgary. It was attended by 150 coal researchers and representatives of the coal industry.

Twenty-nine researchers whose work was supported by the Office in 1987 presented summaries of their investigations in six concurrent sessions.

The following day, speakers from Australia, France, the United States and Canada presented a symposium on spontaneous combustion of coal.

Titles of the workshop and symposium presentations are listed below.

Exploration	Geotechnical	Preparation and Upgrading	Combustion and Pyrolysis
Three-Dimensional Structural Geometries of Imbricated Thrust Sheets	Footwall Anchoring	Coal Comminution	IEA Basic Coal Combustion Science
Surface Geophysical Coal Exploration	Triaxial Test Development	Washery Optimization	Combustion Program Development at the Alberta Research Council/ Combustion Characteristics of Western Canadian Coals
Downhole Geophysical Characterization of Overburden	Behaviour of Coal Measure Rocks	Analysis of Process Yield Losses	Enhanced Oil Recovery Project
In-Seam Coal Characterization	Deformation and Progressive Failure of Open-Pit Highwalls	Properties of Thermally Dried Coal	Pyrolysis/ Hydrolysis
Seismic Modelling of Shallow Coalfields	Models for Monitoring Ground Movement in Coal Mines	Coal Beneficiation Process	

Conversion	Properties and Analysis	Symposium
Gasification Process Research	Chemistry of Coal Liquids	Overview of Spontaneous Combustion of Australian Coals
Gasification of Western Canadian Coals	Functional Group Analysis of Coal Liquids	Spontaneous Combustion Potential of Coal
PYROSOL Process	Isotopic Studies on Coal/Bitumen Co-processing Schemes	Research in France Pertaining to the Problem of Spontaneous Combustion
Supercritical Gas Extraction of Coal	Hydroprocessing of Coal-Derived Liquids	Susceptibility of Canadian Coals to Spontaneous Combustion
Electrolysis of Coal Slurries	Electrochemical Behaviour in Gasification	Chemistry of Spontaneous Combustion
		Overview of Spontaneous Combustion Modelling

The PDU is highly versatile and automated. It can be operated either in the CCLC mode (two-stage hydrogenation) or the PYROSOL mode (hydrogenation/hydrocoking). Toward year-end, a 36-hour continuous run using 40 weight per cent coal was completed. Distillable oil yield was approximately 75 weight per cent of the feed. It is anticipated that PDU studies will eventually lead to pilot-scale PYROSOL tests by GfK.

Two feasibility studies were initiated by Canadian Energy Developments Inc. In one, the potential of adapting co-processing technology to existing refineries as a heavy ends upgrader is being evaluated, while the second study concerns the feasibility of a stand-alone upgrader.

Both studies indicated that, compared with heavy oil upgrading alone, co-processing technology offers significant financial advantages. Although the capital costs are similar to those of heavy oil upgrading, feedstock costs for co-processing are subtantially lower.

Meanwhile, a patent application for the CCLC Process was filed in the U.S.

Publications

Boehm, F.G. and E. St. Denis. 1987. *PYROSOL Co-processing: A Valid Alternative in Resource Upgrading.* Presented at 1987 AOSTRA Conference, Edmonton, Alberta.

Boehm, F.G. and R.D. Caron. 1988. *The Technical and Economical Status of Co-processing Technologies for Canadian Feedstocks.* Presented at 3rd Chem. Congress of North America, Toronto, Ontario.

Chemistry of Coal Liquefaction[1]

ALBERTA RESEARCH COUNCIL, DEVON

The chemical changes that occur when coal is liquefied or bitumen is upgraded are complex and difficult to follow from an analytical perspective. However, when the two processes occur simultaneously, as they do in co-processing, it is even more difficult to understand the chain of events that ultimately leads to products.

Consequently, a project was initiated in 1985 at the Alberta Research Council to gain a better understanding of the transformation processes that occur during coal/bitumen co-processing. The work entailed developing chemical and physical characterization methods for co-processing feedstock and reaction products, and developing a method to characterize product performance. This involved an "analysis tree" comprising the following: separation of high and low molecular weight components; separation of resins from oils; separation of hydrocarbons into saturates and several aromatic fractions; separation of asphaltenes by size; the use of field-ionization mass spectrometry and thermogravimetric analysis; evaluation of structural groupings in asphaltenes by nuclear magnetic resonance; and determination of the octane and cetane indices of the reaction products. These latter indices are important in evaluating synthetic crude oils as potential oil refinery feedstocks. This is done by establishing correlations with cetane number, a method of characterizing gasoline for diesel engines.

Laboratory facilities, such as these, were used to characterize the products of co-processing.

This year a cetane index procedure was developed using nuclear magnetic resonance. Also, a standardized procedure (known as PNA analysis) for analysing paraffins, naphthenes and aromatics was developed. These methods were successfully used to analyse reaction products from a variety of liquefaction processes, including the coal/bitumen co-processing scheme of Canadian Energy Developments Inc. Also, some initial work on the chemical pathways involved in coke formation was carried out.

[1] An Institutional Research Program project

Functional Group Analysis of Coal Liquids[1]

UNIVERSITY OF ALBERTA (M.R. GRAY), EDMONTON

The composition of liquids derived from coal is so complex that it is not possible to identify and quantify every chemical compound. Nevertheless, to understand the mechanisms involved in coal liquefaction or coal/bitumen co-processing, it is necessary to characterize the major reactants and products in some manner.

In this project, initiated in 1986, it was proposed that an approach known as Functional Group Analysis (FGA) be used. It would bridge the gap between analytical techniques capable of dissecting molecules atom-by-atom and physical chemistry measurements that provide a broad indication of certain properties.

Practitioners of FGA view complex molecules as collections of functional groups, such as aromatic rings, alkyl groups or methyl groups, and use various analytical techniques to quantify each of them.

In the first stage of this work, profiles of complex coal liquids were prepared from data supplied by nuclear magnetic resonance spectra, infra-red spectra, nitrogen titration analysis and elemental analyses using computer software developed especially for this project.

In co-operation with staff of the Alberta Research Council (ARC), detailed investigations were made of several coal liquefaction processes. This work incorporated some of the chemical and physical characterization methods developed at ARC (described elsewhere in this section of the report).

FGA was used to relate the quality of liquefaction solvents to improvements in the quality of coal liquefaction products. When Highvale coal was pyrolysed in hydrogen, FGA allowed researchers to follow the stepwise transformation of reactants to products. During coal/bitumen co-processing, it was possible to observe hydroaromatic and naphthenic structures, originating with bitumen, being converted to aromatic compounds. It was also observed that coal caused a hydrogen deficiency that led to the formation of olefins. These are important observations in terms of producing desirable petrochemical feedstocks.

It was concluded that FGA is a valuable analytical concept and should become an integral part of all co-processing studies. It is equally applicable to bitumen or heavy oil upgrading.

Publications

Gray, M.R. and I.G. Dalla Lana. 1987. *Functional Group Analysis of Coal Liquids: Final Report.* University of Alberta.

Jacobson, J.M., M.R. Gray, A.K. Chambers and J. Thiel. 1988. *Structural Compositions of Tars from Hydropyrolysis of Coal. Effect of Reaction Severity.* Energy and Fuels. 2: 316-20.

Egiebor, N.O., J.M. Jacobson and M.R. Gray. 1988. *Structural Group Analysis of Products from Two-Stage Liquefaction of Highvale Coal.* Fuel Sci. Tech. Inst., in press.

[1] A Coal Research Grants Program project.

Isotopic Studies of Coal/Bitumen Co-processing Schemes[2]

UNIVERSITY OF ALBERTA (K. MUEHLENBACHS), EDMONTON[3]

The mixture of products resulting from co-processing and the economics of the process are influenced by the proportions of coal and bitumen used in the feedstock. Therefore, knowing how much each feedstock component contributes to the chemical composition of the products is important, and could be the basis for a useful process control method.

In an earlier project supported by the Office, an analytical technique, known as isotope mass balance, was successfully used to measure the ratio of carbon 13 to carbon 12 isotopes in coal and bitumen. It allowed researchers to differentiate between the carbon derived from coal and the carbon derived from bitumen in the products of coal/bitumen co-processing. It was found that, depending on co-processing conditions, 14 to 23 per cent of the carbon in the resulting synthetic crude oil originated with coal.

This year a new project was begun. It is a co-operative effort involving researchers at the University of Alberta and the Alberta Research Council. They are using the isotope mass balance technique to determine optimum coal/bitumen reaction conditions. Also, the technique is being used to evaluate the results of secondary upgrading schemes aimed at converting co-processing products into synthetic crude oils suitable as feedstocks for conventional refineries.

In addition, the technique is being extended to monitor the fate of nitrogen and oxygen during co-processing.

Coal solubilization in a continuous reactor was successfully monitored, and experiments conducted at 445°C in the presence of iron oxide catalyst were

[2] A Coal Research Grants Program project.

[3] In conjunction with researchers at the Coal and Hydrocarbon Processing Department of the Alberta Research Council.

also monitored to gain an understanding of the factors contributing to coke production.

The isotope mass balance technique demonstrated that secondary upgrading increased the coal-derived carbon of co-processing liquids from 19 per cent to 27 per cent.

Preliminary measurements of the ratio of ^{15}N to ^{14}N revealed a two or three per cent difference for Alberta coals versus bitumen. This suggests that a viable analytical technique is possible.

Hydroprocessing of Coal-Derived Liquids[1]

UNIVERSITY OF ALBERTA (I.G. DALLA LANA), EDMONTON

When coal is liquefied to produce a synthetic crude oil, a wide variety of hydrocarbons is produced. The chemical structures of some of these products are such that they must be altered by subsequent hydrogenation reactions, otherwise the synthetic crude oil cannot be processed in existing oil refineries. Similarly, any sulphur-containing or nitrogen-containing molecules must be hydrogenated to remove these atoms.

To obtain desirable liquids that can be converted into valuable fuels in oil refineries, it is necessary to understand the chemical changes taking place when coal liquids are hydroprocessed. The complex array of chemicals comprising these products makes it virtually impossible to describe individual reactions. Therefore, functional group analysis (described elsewhere in this report) is being used in this project to follow the effects of various hydroprocessing conditions on the amount of sulphur and nitrogen present in the hydroprocessed products.

A coal-derived liquid, produced from liquefaction studies at the Alberta Research Council, was obtained and characterized by functional group analysis.

This feedstock was hydroprocessed in the presence of four catalysts to determine the effects of catalyst and temperature on the reaction chemistry. More than 20 reactor runs were completed.

At year-end, chemical analyses and interpretation of the results were under way, but incomplete.

[1] A Coal Research Grants Program project.

Secondary Upgrading[2]

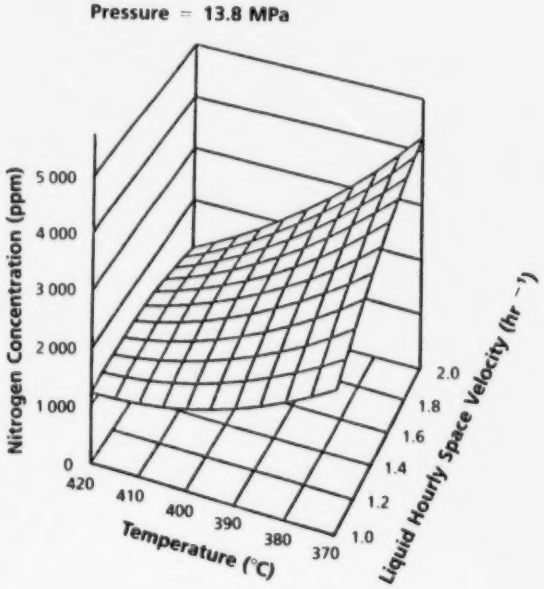
ALBERTA RESEARCH COUNCIL, DEVON

The 200-300°C and 301-524°C fractions of products obtained from coal/bitumen co-processing contain substantially more sulphur and nitrogen than is allowable in refinery feedstocks. Therefore, the objectives of this project were: (1) to examine the options for removal of sulphur and nitrogen, and (2) to quantify the amount of coal-derived carbon incorporated into the products of a conventional, catalytic hydrogenation, secondary upgrading process.

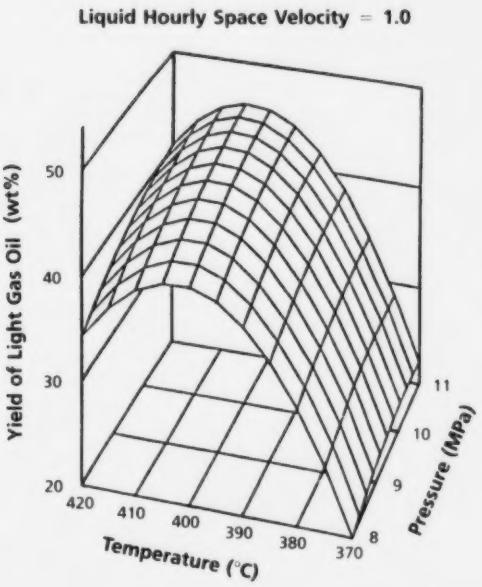
The products from the first stage of co-processed Highvale subbituminous coal and Athabasca bitumen were hydro-treated using a continuous tubular reactor and Ni-Mo/Al_2O_3 catalyst. Upon analysis, it was found that sufficient nitrogen was removed from the products, but the sulphur content of some fractions still exceeded refinery specifications. The hydro-treating process was then used to upgrade certain fractions of product from the co-processing scheme of Canadian Energy Developments Inc., thus demonstrating that most technical obstacles to producing a synthetic crude have been overcome.

[2] An Institutional Research Program project.

Variation of Nitrogen Concentration with Secondary Upgrading Conditions



Variation of Light Oil Yield with Secondary Upgrading Conditions



Using the stable isotope mass balance method, the upgraded products of Highvale coal/Athabasca bitumen co-processing were successfully analysed for coal-derived carbon.

Publications

Muehlenbachs, K., J. Steer, A. Kogg, T. Ohuchi and G. Beaulieu. 1988. *Natural Variations of ^{13}C Abundance in Coal and Bitumen as a Tool to Monitor Co-processing.* 195th American Chemical Society Meeting, Toronto, Ontario, June 5-10.

Muehlenbachs, K., T. Ohuchi, M. Bombin, J. Wilson and A. Chambers. 1988. *The Fate of Coal in Secondary Upgrading of Products from Co-processing Athabasca Bitumen with Subbituminous Coal.* Gordon Research Conference.

Ohuchi, T., J. Wilson, A. Chambers, M. Bombin and K. Muehlenbachs. 1988. *Catalytic Hydrotreatment of the Products from the First Stage of Coal/Bitumen Co-processing.* 38th Canadian Engineering Conference, Edmonton, Alberta.

Supercritical Gas Extraction of Coal[1]

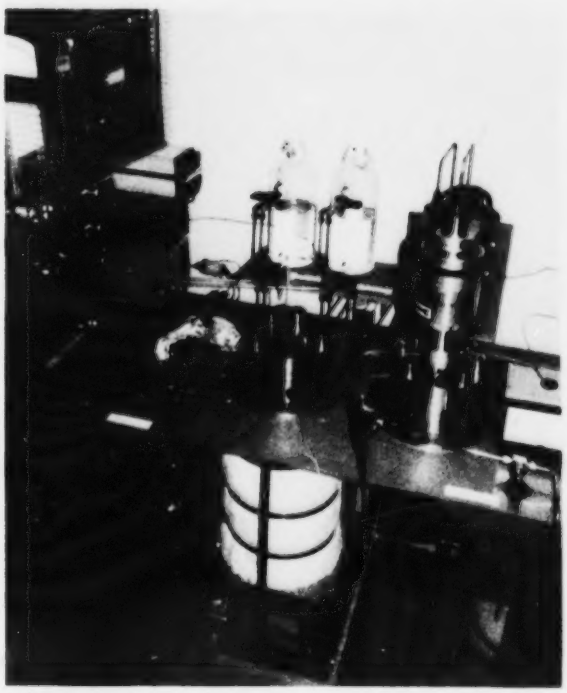
UNIVERSITY OF ALBERTA (N. BERKOWITZ), EDMONTON

In earlier work by this researcher, a water/carbon monoxide mixture at supercritical[2] conditions was used to extract liquids from coal. In those experiments, conversion to toluene-soluble "primary liquids" and gas ranged as high as 50 weight per cent for lignite and 35 weight per cent for high-volatile bituminous coal.

In supercritical gas extraction systems, extraction occurs because the vapour pressures of solid and heavy liquid components of coal are enhanced by contact with the compressed gas. This discovery is important because it represents another method for converting coal to liquids. It may be especially valuable for subbituminous coals because they do not respond well to low-temperature carbonization or flash pyrolysis processes that remove liquids from other types of coal and leave a residual, energy-

[1] A Coal Research Grants Program project.

[2] Critical temperature is the temperature above which a gas cannot be liquefied by pressure alone.



Laboratory experiments using the apparatus shown here are under way to extract hydrocarbon liquids from coal.

enhanced char that can be burned in pulverized fuel-fired boilers.

In this project, initiated in 1986, supercritical gas extraction is being used on several subbituminous coals. Reactions are carried out in a one-litre stirred autoclave operated at temperatures ranging from 400 to 425°C and at pressures between 14 and 25 MPa.

This year, extraction studies at 400°C and 14 MPa using either supercritical water alone, or supercritical water and carbon monoxide, showed that the presence of carbon monoxide in some instances will increase extraction yields by approximately 25 per cent.

This enhancement results almost exclusively in a greater yield of light hydrocarbons. Also, the presence of carbon monoxide reduces the formation of water, which is derived from oxygen-bearing functional groups in the coal. Studies with catalysts are under way to further enhance these results.

Liquefaction of Coal With Natural Gas[1]

UNIVERSITY OF ALBERTA (M.R. GRAY), EDMONTON

One of the drawbacks of conventional coal liquefaction processes is that they depend on the use of expensive hydrogen. In some processes, hydrogen production can account for one-third of the total operating costs.

In this project, an alternative approach is being tried. Instead of producing hydrogen from natural gas, which is commonly done now in Alberta, natural gas (methane) is being used directly as the hydrogenation agent.

In laboratory investigations using a specially designed micro-reactor, liquefaction of Highvale subbituminous coal was carried out using tetralin as a donor solvent and either methane or hydrogen as the hydrogenation gas. Runs with argon, an inert gas, were made to provide baseline conditions. All experiments were conducted at 450°C and 20 700 kPa (3 000 psi). Liquid conversion rates (based on toluene-soluble products) were 51 per cent for hydrogen, 49 per cent for methane and less than 40 per cent for argon.

When the experiments with hydrogen and methane were repeated in the presence of iron oxide catalyst, conversion rates were higher and the increase caused by the catalyst was more pronounced for methane.

[1] A Coal Research Grants Program project.

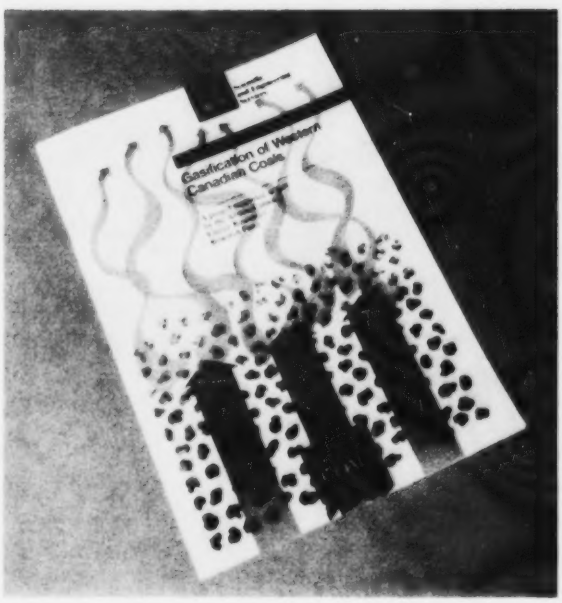
Gasification

Last year, a consortium of sponsors, headed by TransAlta Utilities Corporation, funded an investigation of coal gasification technologies, applications and the potential of using Alberta coal in existing or proposed systems.

The study concluded that Integrated Gasification Combined Cycle (IGCC) systems now under development are demonstrating several advantages over current coal-fired thermal plants. In particular, they produce substantially fewer air emissions than conventional thermal plants.

Therefore, it was recommended that Alberta coal producers and researchers should become actively involved in IGCC developments. Subsequently, the formation of a multi-participant technical committee on gasification was spearheaded by the Office.

Projects which have since evolved are described in the following section. Additional details about coal gasification may be found in the publication *Gasification of Western Canadian Coals*, available from the Alberta Energy/Forestry, Lands and Wildlife Information Centres; see page 62.



Canadian Coal Gasification Technical Committee

Following the completion of a study of coal gasification technologies in 1987, and as a direct spin-off from the Joint Industry/Government Coal Combustion Research Program, a Canadian Coal Gasification Technical Committee was established. It represents[1] Canadian coal producers, utility companies and the federal and provincial governments.

The principal objectives of the committee are:

- by 1994, to design and build a 150 MW (electrical) prototype Integrated Gasification Combined Cycle (IGCC) plant in Canada;
- to establish and standardize coal gasification testing methods for Canadian laboratories; and
- to facilitate performance evaluations of Canadian coals in the various coal gasification technologies.

The program has been divided into five major elements:

- Technology Assessment;
- Coal Characterization;
- Exploratory Experimentation;
- Engineering Systems Design; and
- Applications Research.

Projects associated with these elements are to focus on each of the major steps involved in preparing coal as feedstock for an IGCC plant, as well as on each component of the gasification process.

It is expected that membership in the committee will vary according to the purpose of specific projects. However, participants will join a forum for technical information exchange, provide funding for projects of common interest, contribute to the establishment of national goals and priorities, and be involved in projects carried out co-operatively with international firms and agencies.

[1] *As of March 31, 1988 participants were:* TransAlta Utilities Corporation, Saskatchewan Power, Shawinigan Integ Inc., Shell Canada Limited, Westar Mining Ltd., Monenco Consultants Limited, Luscar Ltd., Alberta Power Limited, Unocal Canada Limited, Esso Resources Canada Limited, Gulf Canada Corporation, Nova Scotia Department of Mines and Energy, Canada Centre for Mineral and Energy Technology, in addition to the Alberta Office of Coal Research and Technology, assisted by the Alberta Research Council.

Gasification Process Research[2]

ALBERTA RESEARCH COUNCIL, DEVON

As interest grows in the subject of coal gasification, it becomes increasingly important to have expertise available to industry to assist with the evaluation of competing gasification technologies and provide appropriate testing and research facilities.

Therefore, the Office provided funding to make it possible for staff of the Alberta Research Council's Coal and Hydrocarbon Processing Department to visit several gasification facilities and sites of gasification research, where they learned first-hand of emerging technologies and recent developments. These visits also helped to establish contacts with gasification researchers from other countries.

This year, laboratories or plants were visited in The Netherlands, the Federal Republic of Germany, the United Kingdom, California, Utah and British Columbia. Processes observed were: Texaco's Cool Water; British Gas Corporation/Lurgi; Krupp-Koppers' PRENFLO; KRW; Royal Dutch Shell; and HT Winkler.

Four visiting scientists gave technical seminars at the Alberta Research Council on various aspects of coal gasification.

[2] An Institutional Research Program project.

Gasification Properties of Alberta Coals[3]

ALBERTA RESEARCH COUNCIL, DEVON

It is critically important that the behaviour of Alberta coals in various gasification technologies be known. This is essential if Alberta utility companies are to make wise choices for the next generation of power plants, and if Alberta coal producers are to effectively market their products elsewhere in the world.

Several properties need to be evaluated to determine the acceptability of coals in any particular gasification system, for example: reactivity under pertinent test conditions; particle size distribution before and during reaction; ash slagging properties; and ash volatility.

In this project, a thermogravimetric analyser (TGA) was used to measure gasification rates of coal chars in carbon dioxide. Measurements of the gasification reactivity were made for Alberta subbituminous (Highvale), low-volatile bituminous (Smoky River) and high-volatile bituminous (Obed) coals, plus a well-

[3] An Institutional Research Program project.

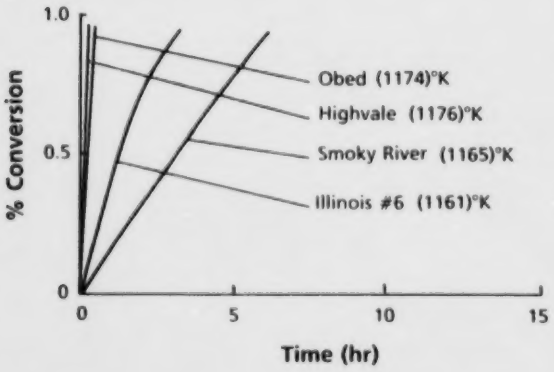
characterized coal from the United States (Illinois No. 6). Gasification experiments were carried out at 700-900°C under carbon dioxide at atmospheric pressure. The effects of particle size, heating rate and gasification temperature on char reactivity were investigated. It was found that heating rate strongly influenced the results for every char. This was especially true for highly reactive coal.

Gasification reactivity increased with decreasing coal rank, although the Alberta high-volatile bituminous coal was more reactive than the United States bituminous coal. An attempt to derive reactivity coefficients from the TGA data, to enable development of a numerical model capable of predicting char reaction rates, was curtailed because of instrument limitations.

Subsequently, a laboratory-scale fixed bed gasifier, designed and built at the Alberta Research Council (and referred to in the project "Gasification Laboratory Facilities") was developed to provide the required data.

The project demonstrated that Alberta coals gasify well at high heating rates, and it indicated that Alberta coals are well-suited for entrained bed gasification technology.

Comparison of Coal Char Reactivities in CO_2 Atmosphere



Gasification Laboratory Facilities[1]

ALBERTA RESEARCH COUNCIL, DEVON

The purpose of this project was to develop laboratory-scale facilities (coal feed rate less than 1 kg/h) at the Alberta Research Council to allow measurement of the gasification properties of Alberta coals in fixed bed, fluidized bed and entrained bed gasification systems.

An existing laminar flow combustion unit was modified to allow entrained flow gasification studies with air feed.

A fixed bed reactor was designed, built and commissioned. Equipment and procedures were developed to perform high-heating rate coal gasification studies. The results of initial investigations are described in the project "Gasification Properties of Alberta Coals."

Construction of a fluidized bed reactor was postponed, however. Studies involving this type of gasification system are being undertaken through a co-operative program with the University of British Columbia. A similar arrangement was made with the Canada Centre for Mineral and Energy Technology for access to an entrained flow reactor.

A powerful Sun 4/260 microcomputer was acquired, and software was purchased and developed to facilitate single particle and equilibrium modelling studies. This equipment enables the execution of in-depth fundamental modelling studies, as well as equilibrium modelling of a more practical nature such as gasification product gas predictions. This equipment will also enable larger-scale gasification and combustion reactor modelling studies.

With the provision of these facilities, it is now possible to conduct coal characterization studies in co-operation with other coal gasification researchers across the full range of commercial or near-commercial technologies, and provide a valuable support service for other Alberta gasification investigations.

[1] An Institutional Research Program project.

Gasification Behaviour of Alberta Coals[1]

ALBERTA RESEARCH COUNCIL, DEVON

In this project, the objective was to test typical Alberta coals in existing laboratory-scale or bench-scale gasification equipment representing the principal types of coal gasification systems, namely fixed bed, fluidized bed and entrained bed.

Operators of test facilities identified in the "Gasification Process Research" project were contacted and arrangements were made for testing.

At year-end, testing of Highvale and Coal Valley coals at the University of British Columbia fluidized bed facility was completed, but data evaluation was still under way. Meanwhile, five coals supplied by five Alberta coal producers were evaluated for their suitability and performance in Texaco, Shell and British Gas gasifier technologies. Testing was completed, but final reports had not been provided by the various laboratories at year-end.

Progress was made in developing a numerical model of coal gasification. This included development of a single particle boundary layer model and prediction of gasifier product gas composition. Based on published data, as well as results from the University of British Columbia tests and coal evaluation tests, techniques were developed to predict product gas composition for several existing gasification technologies.

Publication

Ozum, B., A. Chambers and G. Kovacik. 1988. *Boundary Layer Model for Char Combustion and Gasification.* Alberta Research Council. (Submitted to Combustion and Flame)

[1] An Institutional Research Program project.

Fluidized Bed Gasification of Highvale Coal[2]

TRANSALTA UTILITIES CORPORATION (CALGARY) AND OTHER PARTICIPANTS[3]

Bench-scale testing has shown that subbituminous coals are likely to be among the most suitable Alberta coals for gasification. Therefore, this project was initiated to test the performance of Highvale coal, a typical Alberta subbituminous coal, in a pilot-scale gasification plant, and to relate the results to a proposed commercial design of an Integrated Gasification Combined Cycle power plant for Alberta.

Twenty-five tonnes of Highvale coal were shipped to Waltz Mill, Pennsylvania, and gasified at the KRW Energy Systems facility, the only pilot-scale fluidized bed gasification plant operating in North America.

A preliminary report of the test results indicated that Highvale coal gasified well, with carbon use of 81 to 89 per cent. Although pilot plant results did not duplicate commercial performance, they did confirm the suitability of Highvale coal in the KRW fluidized bed gasifier.

Because the sulphur content of coal was very low, a satisfactory sulphur material balance was not achieved. Sulphur capture, however, was estimated to be as high as 77 per cent. Similar tests using other reactor types are planned.

[2] A Strategic Research Program project.

[3] *Other participants are:* Esso Resources Canada Limited, Unocal Canada Limited, Gulf Canada Corporation, Luscar Ltd., Alberta Power Limited and the Canada Centre for Mineral and Energy Technology, in addition to the Alberta Office of Coal Research and Technology.

Economics of Coal Gasification[4]

ALBERTA POWER LIMITED, EDMONTON AND OTHER PARTICIPANTS[5]

Following the gasification technology review carried out last year by TransAlta Utilities Corporation, it was decided that an economic analysis of gasification applications in Alberta should be undertaken.

Therefore, Alberta Power Limited, on behalf of the Canadian Coal Gasification Technical Committee, commissioned Monenco Consultants Limited of Calgary to study the economics of three options: (1) operation of a 150 MW Integrated Gasification Combined Cycle (IGCC) plant to produce electricity; (2) operation of a combined 150 MW IGCC plant to produce electricity and a 13 000 kg/h (28 600 lb./hr.) methanol plant; and (3) operation of a 33 000 kg/h (72 600 lb./hr.) plant to produce methanol alone.

In all three cases, it was assumed that Highvale subbituminous coal would be the feedstock and a Texaco gasification system would be used.

The consultants used an engineering economics model in the form of a Lotus 1-2-3 spreadsheet. The model is based on published data from the Cool Water demonstration project in the U.S., and from Monenco's experience with utility companies and chemical plants in Alberta.

[4] A Strategic Research Program project.

[5] *Other participants are:* TransAlta Utilities Corporation, Esso Resources Canada Limited, Gulf Canada Corporation and Luscar Ltd., in addition to the Alberta Office of Coal Research and Technology.

The analyses revealed that production of electricity alone from coal gas is not economically viable at present, but co-production and production of methanol alone probably are.

As more information about the gasification properties of Alberta coals becomes available, it is likely that further refinements to the model will be appropriate.

Publication

Economic Studies of Gasification Applications. 1987. Monenco Consultants Limited.

Corrosion in Gasification Systems[1]

UNIVERSITY OF CALGARY (W.J.D. SHAW), CALGARY

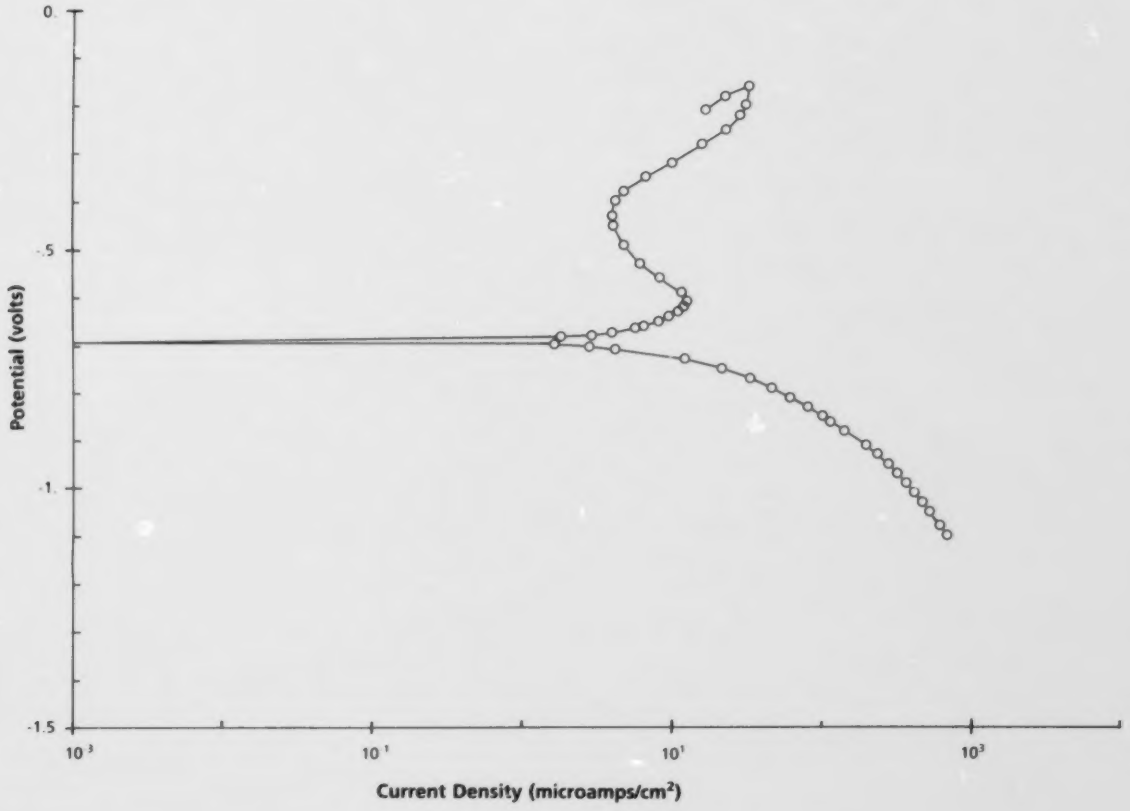
Equipment failures that have occurred during start-up or shut-down in gasification plants are believed to have been caused by aqueous corrosion or stress corrosion cracking.

While various metals have been tested in pilot-scale gasification operations, little is known about the corrosion mechanisms that occur in gasification environments. This information can best be obtained from studies of the electrochemical behaviour of selected materials exposed to simulated gasification conditions.

In this project, a potentiostat was used to measure the electrochemical properties of several alloys, and a scanning electron microscope was used to examine the condition of exposed metal surfaces. Eleven alloys were exposed to an aqueous solution containing salts, while various gas combinations were passed through the solution. The gases consisted of nitrogen, carbon dioxide, hydrogen sulphide, carbon monoxide, hydrogen, ammonia and methane. These experiments were designed to simulate closely the conditions found in pilot-scale gasification plants.

[1] A Coal Research Grants Program project.

Potentiodynamic Scan of Pyromet 751



Of all the alloys tested, it was found that Fe-30Mn-8Al exhibited the lowest corrosion rate and showed the least sensitivity to variations in the gasification environment. This alloy outperformed the expensive nickel-based materials as well as other conventional stainless steels. It shows considerable promise for use in coal gasification plants and is especially attractive because of its low cost.

Among standard alloys, the best performers were those containing iron plus 20 to 25 per cent chromium and 15 per cent nickel. High nickel contents were found to be detrimental. Alloys containing cobalt or molybdenum also did not perform well.

Most of the alloys formed thin protective surface films, but the film formed by the Fe-Mn-Al alloy was thick and tenacious. Pyromet 751 formed a film that cracked, while Udimet 700 formed a film with holes. Neither was able to provide adequate corrosion protection.

The data base resulting from this project should be useful for designers of gasification plants and for materials suppliers involved in the development of new materials.

Publications

Shaw, W.J.D. and D.M. Jayasinghe. 1987. *Electrochemical Behaviour of Materials for Coal Gasification Environments.* Coal Research Workshop and Symposium, November 12-13, University of Calgary.

Jayasinghe, D.M. 1988. *Aqueous Corrosion of Select Materials in Simulated Coal Gasification Environments.* M.Sc. Thesis, Department of Chemical Engineering, University of Calgary.

Shaw, W.J.D. and D.M. Jayasinghe. 1989. *Corrosion Comparison of Materials in a Simulated Coal Gasification Environment.* Microstructural Science, Vol. 17, in press.

Transportation

Except for subbituminous coal, which is consumed in Alberta at mine-mouth thermal power plants, Alberta's other coal products must be shipped long distances to market. Therefore, transportation costs make a significant contribution to the delivered costs of Alberta coals. For example, transportation by rail accounts for 35 per cent of all the costs to mine, clean and deliver Alberta coals to Pacific ports.

As an alternative to rail haul, the concept of moving coal slurries to market in a pipeline has been studied twice in Alberta since 1980. Each investigation has indicated that, within certain limits, coal pipelining to the west coast or Ontario is viable. (Further details about these studies are provided in the Office publication, *An Economic Analysis of Coal Pipeline Systems*, available from the Alberta Energy/Forestry, Lands and Wildlife Information Centres, see page 62.)

Given the current priority of reducing the delivered cost of Alberta coal in Ontario, additional coal pipelining investigations were launched this year. They are described in the following section.

Coal Market Access Model[1]

TRIMAC CONSULTING SERVICES LTD., CALGARY

Transportation and handling costs represent more than half the purchase price that Ontario buyers pay for Alberta coal, making it difficult for coal from Alberta to compete in the Ontario market with coal from Ohio or other eastern U. S. locations. Alberta coal, however, contains considerably less sulphur, making it attractive to Ontario consumers whose combustion equipment must be capable of satisfying emission limits for sulphur oxides.

Besides transportation costs, Alberta coals have another disadvantage: they contain less combustible carbon per unit weight than eastern U.S. coals. Therefore, if Alberta coal producers are to improve their sales in Ontario, the energy content of the product must be raised and some means must be found to lower the transportation costs. Although on an energy-content basis, some haulage cost reduction will result from shipping coal containing less moisture and mineral matter, technical improvements are needed at virtually every stage in the mine-to-market chain before the delivered costs of Alberta coal will be competitive in Ontario.

[1] A Strategic Research Program project.

To obtain some measure of the effects of these various technological options on delivered costs, this project aims to create a computer model capable of systematically evaluating each option. This also includes identifying opportunities for improved efficiency where new technologies currently do not exist.

Ultimately, the model could be developed to assess markets other than Ontario.

This year, a data base was assembled with information about coal production, power plant operation, coal transportation and handling, upgrading technologies, coal blending opportunities and the likely demand for thermal coal in Ontario. As a demonstration of the model's capabilities, data assembly was limited to assessing the production of a foothills thermal coal and its delivery to Ontario Hydro's Nanticoke electricity-generating station.

With successful demonstration of this phase of the project, it was proposed that the model be refined to make it more "user friendly" and readily available to the coal industry. Subsequent development could include expansion of the model to include coal supply from all production locations in western Canada, with delivery to both Ontario and Cold Lake. The latter market is included in anticipation of using coal for steam-raising in enhanced oil recovery. At year-end, coal producers were being encouraged to participate in subsequent phases of this project.

Coal-Oil Slurry Pipelining[1]

UNOCAL CANADA LIMITED, CALGARY

It has been estimated that the cost of transporting Alberta coal to Ontario can be reduced by at least 25 per cent if slurries of coal and oil are pumped through existing oil pipelines, rather than being shipped in bulk by rail as is done now.

Before the commercial potential of such a scheme can be ascertained, however, a detailed analysis must be made of alternative methods for introducing coal-oil slurries into pipelines. For instance, assuming the pipeline is also used to transport oil, the question of whether oil is contaminated by coal must be addressed. Also, concerns have been raised as to whether coal-oil slurries will be abrasive enough to erode the metal of the pipeline and pumps. Furthermore, the feasibility of the concept depends on an ability to produce stable slurries economically and separate them into their respective coal and oil components at the other end of the pipeline.

In this project, which is expected to continue, several activities were undertaken this year. The effect of particle size distribution on coal-oil slurry characteristics was assessed, and different techniques for separating coal-oil slurries were evaluated.

It was found that the viscosity of coal-oil slurries can be controlled and pipeline-stable slurries can be created. It is possible to separate clean oil from the slurry. Although separation of oil from the slurry leaves a coal residue having a higher-than-desired oil content, indications point to a successful resolution of this problem. Several patent applications have been identified.

Pipeline loop tests at the Saskatchewan Research Council are planned for next year. Also, Trans Mountain Pipe Line Company Ltd., which operates an oil pipeline system between Alberta and the west coast, has become involved in the project in an advisory capacity. This is expected to lead to a large-scale pipeline batch test.

[1] A Strategic Research Program project.

Coal/Oil/Natural Gas Transportation System[2]

CERI ENERGY RESEARCH LTD., CALGARY

Together with studies addressing the technical aspects of coal-oil slurry pipelining, an economic cost/benefit analysis of the concept is necessary. Also, an early identification of political/economic/system issues that are likely to arise if slurry pipelining proceeds is equally essential. These aspects of coal-oil slurry pipelining were investigated in this project.

Results of this study indicated, in general terms, that coal-oil slurry pipelining offers several economic advantages and the concept is viable.

[2] A Strategic Research Program project.

Coal Slurry Technology[1]

SALZGITTER INDUSTRIEBAU GmbH,
FEDERAL REPUBLIC OF GERMANY

In this collaborative[2] project, an investigation is being made of the technical and economic feasibility of producing, transporting by pipeline and burning a coal-water slurry fuel made from Alberta coal using Salzgitter's DENSECOAL process. This is another alternative transportation scheme for lowering the delivered cost of coal in Ontario and other markets.

Six Alberta coals were tested by Salzgitter to determine their suitability for producing fine-grained, highly concentrated (70 weight per cent solids) coal-water fuels. It was found that slurry concentration was rank dependent. With medium volatile coals, it was possible to produce stable suspensions having a solids concentration of 70 weight per cent, but the low-rank subbituminous coals produced unsuitable slurries containing less than 60 weight per cent solids.

Following these screening tests, a medium volatile and a high volatile bituminous coal were selected for larger-scale slurry production. Ten-tonne samples of each were slurried by Salzgitter. Five tonnes of each slurry were delivered to the CANMET laboratories at Bells Corners (near Ottawa) for combustion tests, while pipeline and transportation stability tests were performed on the remainder by Salzgitter. This work was still under way at year-end.

[1] A Strategic Research Program project.

[2] *Jointly funded by:* Ontario Hydro, Maritime Electric Company Limited, Trans Mountain Pipe Line Company Ltd., Interprovincial Pipe Line Limited, several coal producers, Bundesministerium für Forschung und Technologie (Federal Republic of Germany), and Energy, Mines and Resources Canada, in addition to the Alberta Office of Coal Research and Technology.

Environment

Environmental issues must be addressed in each of the projects funded by the Alberta Office of Coal Research and Technology, whether the concern is land reclamation, habitat disturbance or the discharge of contaminants into water bodies or the atmosphere.

This is consistent with a growing awareness by Alberta's coal producers that economic development and environmental protection must proceed hand-in-hand. For example, when mining activities cease in open-pit mines, the previously removed overburden must be replaced in such a manner that native vegetation or crops can be grown. Also, in considering future electricity-generating technologies for Alberta, utility companies find coal gasification to be attractive, partly because it produces fewer air emissions. As well, one of the most important advantages of using low-sulphur Alberta coal in Ontario is that fewer sulphur oxides will be produced during combustion. These are but a few examples of the environmental considerations inherent in each project supported by the Office. Two projects wholly concerned with environmental protection are described in the following section.

Coal Conversion Waste-Water Treatment[3]

UNIVERSITY OF ALBERTA (S.E. HRUDEY), EDMONTON

In the course of liquefying or gasifying coal, waste waters are produced which contain a wide variety and substantial quantities of organic compounds. These process effluents cannot be discharged into water bodies without first undergoing treatment to remove undesirable chemicals.

Before this project began, research had indicated that anaerobic biological treatment might be a cost-effective method of removing organic material from waste waters. However, it was also found that removal of phenolic compounds (the most prevalent and least-desired components of coal liquefaction waste waters) was inhibited by the presence of non-phenolic substances.

Therefore, the objective of this project was to explore various methods of removing these substances in a cost-effective manner to allow biological conversion of phenols to methane. The approach involved solvent extraction and pH control.

[3] A Coal Research Grants Program project

Coal liquefaction waste water was obtained from the H-Coal pilot plant in Kentucky. After the pH was adjusted to between 7.0 and 11.5, the samples were solvent-extracted with diisopropyl ether (DIPE) and exposed to nutrients and anaerobic digestion sludge for six weeks.

It was found that conversion of phenol to methane was no longer inhibited following solvent extraction by DIPE. This demonstrated that inhibitors were successfully removed.

The results indicated that H-Coal waste water, extracted in the pH range 8.5 to 10, would be free of inhibitors while consuming optimal quantities of pH-control chemicals.

Subsequently, waste water which had been solvent-extracted with DIPE at pH9 was treated continuously with anaerobic cultures. These experiments were successful.

Publications

Fedorak, P.M. and S.E. Hrudey. 1986. *Anaerobic Treatment of Phenolic Coal Conversion Wastewater in Semicontinuous Cultures.* Water Res. 20:113-122.

Kindzierski, W.B., S.E. Hrudey and P.M. Fedorak. 1988. *Solvent Extraction and Anaerobic Biological Treatment of a High Strength Phenolic Wastewater.* To be presented at Joint CSCE-ASCE National Conference on Environmental Engineering, July 13-15.

Coal for Use in Enhanced Oil Recovery: Emission Control Technology[1]

ESSO RESOURCES CANADA LIMITED, CALGARY

The sulphur content of some Alberta subbituminous coals is sufficiently low that current, new-source emission regulations can be met without sulphur oxide emission control. However, for most Alberta subbituminous coals, some degree of flue gas clean-up or control will be required. If coal-fired boilers are to be used in the future at in situ heavy oil recovery operations (see MARKETS section), they must be capable at least of satisfying existing regulations and meeting even more stringent guidelines that might be introduced for sulphur oxide (SOx) and nitrogen oxide (NOx) emissions.

Therefore, the purpose of this project was to identify appropriate NOx and SOx emission control technologies to be incorporated into the coal-fired boilers now being designed for in situ heavy oil recovery operations.

The investigation, subcontracted to Monenco Consultants Limited of Calgary and co-ordinated by Esso Resources Canada Limited on behalf of the Coal-Fired Steam Generation for Heavy Oil Recovery Technical Committee, involved an evaluation of in-furnace and post-combustion emission control technologies. The in-furnace technologies were: furnace sorbent injection; multi-stage burners; fuel staging; advanced external combustors including slagging combustors; and non-selective catalytic reduction. The post-combustion control technologies were: selective catalytic reduction; duct sorbent injection; calcium injection; lime spray drying; wet limestone and lime scrubbing; and dual alkali.

It was concluded that the most cost-effective approach to emission control would be to use in-furnace technology as much as possible, and supplement it with post-combustion control if emission standards become even more stringent in the future. Depending on coal quality, it was predicted that NOx and SOx emissions would range from 50 to 100 per cent of currently regulated limits for new coal-fired sources using in-furnace technology.

For the present, it was recommended that a combination of furnace sorbent injection and multi-stage burners be used. Several add-on technologies were suggested in the event of more stringent standards.

[1] A Strategic Research Program project.

Sorbent Injection Technical Committee

On October 15, 1987, the Sorbent Injection Technical Committee[2] was established to pursue investigations involving the injection of alkali metal sorbents into coal-fired furnaces to capture acid-forming gases in the form of easily extracted particulates. The committee's principal objective is to establish whether or not sorbent injection is viable for sulphur gas emission control in Alberta.

At year-end, the committee was preparing a list of proposed projects for 1988/89.

[2] *Initial participants were:* Esso Resources Canada Limited, Edmonton Power, TransAlta Utilities Corporation, Alberta Power Limited, Luscar Ltd., Monenco Consultants Limited and the Alberta Office of Coal Research and Technology.

Markets

In the four years since the Alberta Office of Coal Research and Technology was established, it has become apparent that some market opportunities for Alberta coals can be created or improved by technological innovation. This is especially true when researchers, governments, industry representatives and coal users work together to solve problems of mutual interest. The following three projects are examples of this collaborative approach.

Coal Use in Enhanced Oil Recovery[1]

LUSCAR LTD. (EDMONTON) AND OTHER PARTICIPANTS[2]

In 1985/86, the Office and several agencies financed a study entitled *Fuel Options for Enhanced Hydrocarbon Recovery*. The investigation, carried out by L.A. Smith Consulting & Development Ltd., concluded that it was cost-effective for oil companies to use coal instead of natural gas to generate steam needed for enhanced recovery of heavy oil. In fact, the study showed that more coal might eventually be needed for this purpose than is now used to generate electricity in Alberta. This implies a potentially major expansion of Alberta's subbituminous mining operations. (Details may be found in the Office publication *Opportunities to Use Coal in Enhanced Oil Recovery* available from the Alberta Energy/Forestry, Lands and Wildlife Information Centres; see page 62.)

The study also noted that to use coal successfully in enhanced oil recovery schemes, a specially designed, pulverized coal-fired boiler was needed.

Subsequently, the Coal-Fired Steam Generation for Heavy Oil Recovery Technical Committee was formed. It proposed a four-stage development program as the next step in using coal for enhanced oil recovery. This project was the first stage of that program.

Boiler manufacturers were asked to propose designs for an innovative coal-fired steam generator. They were informed that the boiler would use pulverized coal, the boiler feedwater would contain a high total dissolved solids concentration, the steam generation capacity should be 25 to 50 kg/s (180 000 to 200 000 lbs./hr.), and modular construction was required to allow truck transportation to field production sites.

Proposals received from two companies were regarded as approximately equal. One, from Combustion Engineering Canada Inc., proposed to burn coal which had been pulverized so that 70 per cent of the particles passed a 200 mesh (74 micron) screen. The other proposal, submitted by Struthers-TIW Ltd., involved combustion of micronized coal, a concept new to Alberta. It would burn coal that was pulverized to allow 90 per cent of the particles to pass a 325 mesh (43 micron) screen.

It was decided that both combustion systems looked promising. Consequently, the technical committee decided it would support development of Combustion Engineering Canada Inc. technology, while one of the committee members (Esso Resources Canada Limited) would also continue to investigate the Struthers-TIW system. At year-end, both boiler manufacturers had been asked to proceed with engineering designs.

[1] A Strategic Research Program project.

[2] *Other participants are:* Fording Coal Limited, Esso Resources Canada Limited and Unocal Canada Limited, in addition to the Alberta Office of Coal Research and Technology.

Coal-Fired Steam Generation for Heavy Oil Recovery Technical Committee

Included among five research areas recommended in 1985/86 by the Joint Industry/Government Coal Combustion Research Program as worthy of further investigation, was one focusing on coal use in enhanced oil recovery. In part, this recommendation was based on findings of the *Fuel Options for Enhanced Hydrocarbon Recovery* report by L.A. Smith Consulting & Development Ltd.

In 1986, a group of companies[1], along with the Alberta Research Council and the Alberta Office of Coal Research and Technology, proposed a four-stage development program as the next step in using coal for enhanced oil recovery.

To implement the program, the Coal-Fired Steam Generation for Heavy Oil Recovery Technical Committee was created in 1986/1987. It represents financial sponsors of individual projects and contracts technical work to the private sector, universities and others at the discretion of the participants.

As of March 31, 1988[2], the research program comprised the following eight components:

1. *Combustion Concepts*
   This phase was completed when two boiler manufacturers proposed designs for coal-fired combustors suitable for steam raising. It is the subject of the "Coal Use in Enhanced Oil Recovery" project described elsewhere in this section.
2. *Systems Development and Design*
   This refers to the two boiler designs being developed in the project "Coal-Fired Steam Injection Boiler" under the direction of Fording Coal Limited. It is expected to lead to the construction of a prototype unit.
3. *Emission Controls*
   One project in this program component was completed this year. It was "Coal for Use in Enhanced Oil Recovery: Emission Control Technology," under the direction of Esso Resources Canada Limited. (See ENVIRONMENT section for project description.)
4. *Fuels Testing*
   A range of Alberta coals will be tested to allow combustion performance and emissions generation to be predicted when these coals are burned in either of the two boilers now being designed.
5. *Transportation and Handling*
   Alternative coal transportation and handling methods are to be evaluated to achieve the best conditions of economics and logistics, with minimum environmental disruption.
6. *Ash Disposal and Use*
   Results from the Fuels Testing component should allow bottom ash and fly ash characteristics to be predicted. This will lead to an evaluation of ash disposal/use alternatives.
7. *Prototype Siting*
   The prototype unit proposed for this program will be located and tested in the field. Its exact location will be decided later.
8. *Public Information*
   As required, the general public, as well as coal companies and the petroleum industry, will be kept informed as the program progresses.

This development program is anticipated to cost over $10 million. The potential benefits, however, could be several times this amount in terms of domestic coal sales and lower steam production costs.

Therefore, coal companies, oil firms and other interested parties are invited to participate in the various project phases to obtain access to the technology. Without their participation, it is unlikely the program will proceed.

An Office publication, *Opportunities to Use Coal in Enhanced Oil Recovery*, is available from the Alberta Energy/Forestry, Lands and Wildlife Information Centres; see page 62.

[1] *Initial corporate participants were:* Esso Resources Canada Limited, Fording Coal Limited, Luscar Ltd., Obed Mountain Coal Company Limited and TransAlta Utilities Corporation.

[2] *Committee members* on March 31, 1988 were: Esso Resources Canada Limited, Fording Coal Limited, Luscar Ltd., TransAlta Utilities Corporation, Alberta Power Limited, Alberta Office of Coal Research and Technology and other observers. Delta Projects Inc. provides co-ordination and promotional services to the committee.

Coal-Fired Steam Injection Boiler[1]

FORDING COAL LIMITED, CALGARY
AND OTHER PARTICIPANTS[2]

Fording Coal Limited, on behalf of the Coal-Fired Steam Generation for Heavy Oil Recovery Technical Committee, contracted Combustion Engineering Canada Inc. to proceed with a design and cost study for a 190 GJ/h (180 million BTU/hr.) pulverized, coal-fired boiler suitable for use in enhanced oil recovery operations.

Some additional economic and infrastructure studies have been identified and initiated. Once they are complete, it is anticipated that the participants in this project will enter into a commercial agreement with a heavy oil producer to test the technical and economic viability of this new coal-fired boiler.

[1] A Strategic Research Program project.

[2] *Other participants* are: Luscar Ltd., Esso Resources Canada Limited, TransAlta Utilities Corporation, Shell Canada Limited and Alberta Power Limited, in addition to the Alberta Office of Coal Research and Technology.

Activated Carbon from Coal[3]

UNIVERSITY OF CALGARY (E.L. TOLLEFSON), CALGARY

As Alberta's population grows, the demand for clean water and the activated carbon used in water purification is expected to rise.

In producing activated carbon from coal, manufacturers tend to use proprietary processes designed to work best with individual types of coal.

In this project, the objective was to design an activated carbon reactor capable of handling a variety of coals. This was to be achieved by providing methods of controlling many of the process variables and conditions. An additional objective was to publicize the operating conditions so as to encourage more manufacturers to enter the field.

A dual-chamber kiln, measuring 3.7 m (12 ft.) in length and having a diameter of 20.3 cm (8 in.), was designed and constructed. It comprises a "preheater-devolatizer" chamber and an "activation" chamber. Paddles attached to a rotating shaft move material through the two chambers of the slightly inclined kiln.

[3] A Coal Research Grants Program project.

The kiln was used to complete 14 semi-continuous production runs using Coal Valley high volatile bituminous and Montgomery subbituminous coals from Alberta, as well as Bienfait lignite coal from Saskatchewan.

The following physical properties were obtained for some selected activated coals:

	Bienfait	Montgomery	Coal Valley
Total Surface Area m^2/g	511	510	345
with pore radius <18Å	416[4]	403[4]	293[4]
with pore radius >18Å	95[4]	107[4]	52[4]
Iodine No.	478	533	436
Phenol No.	62	56	56
Methylene Blue No.	64	80	33
Ash content, %	21.9	31.8	19.7
Yield, % dry basis	48.3	42.3	50.3
Bulk Density, g/cc	0.495	0.486	0.488

[4] Calculated values

This demonstrated that the kiln can be used to produce activated carbon from low-rank Alberta coals and screen coals for their suitability as feedstocks for production of activated carbon.

Publication

Hall, E.S. and E.L. Tollefson. 1987. *Preparation of Activated Carbon From Some Alberta Coals.* Proceedings 37th Canadian Chemical Engineering Conference, Montreal, May 18-22.

Other Projects

Five studies were undertaken this year in which some fundamental properties of coal were investigated. Some of these studies were in support of other projects or program areas, while others represent new areas of interest. They are described in the following section.

Electrolysis of Coal Slurries[1]

UNIVERSITY OF CALGARY (V.I. BIRSS), CALGARY

Research studies in several laboratories have shown that hydrogen is readily and inexpensively produced when acidic coal slurries are electrochemically oxidized. Furthermore, other gases of commercial importance, such as carbon monoxide and carbon dioxide, can be produced in a pure state.

Because most studies have been carried out in the United States using U.S. coal, this project was initiated to determine the feasibility of using electrochemical methods to oxidize Alberta coals. An additional objective was to determine whether correlations exist between oxidation rates and coal rank or origin.

During the first year of this project, coals originating from four mines (Highvale, Coal Valley, Vesta and Bow City) were pulverized and slurried in a mixture of sulphuric acid and ferrous sulphate. The slurries were exposed to an electric current at room temperature to produce hydrogen and various oxidized coal products.

This year, experiments were carried out at 90°C. A second order kinetic analysis of the electrochemical data produced rate constants for the process. They correlate well with the aromaticity and fixed carbon content of the various coals. In decreasing order, the electrochemical activity was found to be Highvale, Coal Valley, Vesta and Bow City.

This research work resulted in several new methods of regenerating the coal surface to allow high reaction rates over oxidation periods extending up to 25 hours.

Electrochemical oxidation was also carried out in acetic acid slurries. Higher reaction rates and concentrations of low molecular weight organic compounds were observed, but less carbon dioxide was produced than in sulphuric acid slurries. Also, the use of certain chemicals in place of ferrous sulphate to mediate the coal oxidation reaction resulted in rate constants that were 100 times higher than with iron.

The project demonstrated that electrochemical conversion of coal to commercially useful products is a promising technology worthy of further development.

Publication

Birss, V.I., G. Thomas and M. Chettiar. 1988. *Electrolysis of Alberta Coal Slurries, Final Report.* Department of Chemistry, University of Calgary.

[1] A Coal Research Grants Program project.

Distributed Chemical and Physical Properties of Coal[2]

UNIVERSITY OF ALBERTA (P.J. CRICKMORE), EDMONTON

Depending on the purpose of the analysis, analytical investigations of coal can be divided into two groups: (1) those that attempt to extract minute details about particular components and properties; and (2) those that aim to relate generalized properties of coal to certain behavioural characteristics to provide a simple method of making predictions about those characteristics. This project represents the latter group.

It is based on the premise that chemical and physical properties of coal are spatially distributed, and a statistical analysis of these distributions can lead to predictions about coal behaviour in, for example, combustion, liquefaction or gasification processes. Furthermore, it is believed that these distributions, whether on a macro scale (such as in a coal seam) or a molecular scale, are not independent of each other.

In this project, a branch of mathematics called fractal analysis is being used to derive relationships between underlying distributions of coal attributes and observed chemical or physical properties.

Following a literature review on the subject, an examination was begun of coal-derived liquids. Asphaltene content and molecular weight distributions were tracked and compared with other chemical and physical properties. At year-end, some relationships were becoming apparent.

[2] A Coal Research Grants Program project.

Magnetic and Electric Properties of Alberta Coals[1]

UNIVERSITY OF CALGARY (H.A. BUCKMASTER), CALGARY

In this project, sophisticated analytical procedures are being used to investigate coal on a molecular scale. Information about the electronic structure of atoms and molecules, and the bonds formed between various components of coal, is being obtained by Continuous Wave Electron Paramagnetic Resonance (CWEPR), Electron Spin Echo (ESE) and Pulse Field-Sweep EPR analyses. This is expected to provide useful insights about free radical reactions that occur when coal is converted to liquid hydrocarbons. These reactions have also been implicated in the spontaneous combustion of coal.

This year, research efforts were concentrated on designing and assembling the analytical equipment. A temperature controller, used to heat coal samples during EPR analysis, was designed and constructed. A 2 GHz ESE spectrometer was assembled; at year-end, some testing had begun.

A pioneering dynamic 9 GHz CWEPR study of selected Alberta coals was completed. The effect of various preliminary treatments, as well as exposure to moisture and air while the sample was heated to spontaneous combustion temperature, was studied. The influence of maceral and mineral content was also investigated.

[1] A Coal Research Grants Program project.

Sulphur Isotope Studies of Coal[2]

UNIVERSITY OF CALGARY (R.H. KROUSE), CALGARY

By studying the various isotopes of sulphur present in naturally occurring, sulphur-containing substances, scientists are gaining a better understanding of the processes that formed marine sediments and petroleum.

This world-wide interest in sulphur isotope analyses led to the present project. It uses sulphur isotope analytical techniques to identify and quantify the various forms in which sulphur occurs in coals. This is important because it relates to the methods used to remove sulphur from coal and to the analysis of liquids produced by coal conversion processes.

In previous work, the researchers developed a non-isothermal, pyrolysis-stable isotope technique to study forms of sulphur (and other elements) in fossil fuels. The technique involves heating a substance in a quartz reactor and analysing the evolved gases. In this case, the gas is hydrogen sulphide (H_2S).

In this project, coals from several Canadian sources – including low-sulphur Alberta coal and high-sulphur coal from Nova Scotia – are being analysed by the pyrolysis-stable isotope technique and other methods, including Kiba Extraction, which is claimed to be capable of distinguishing between pyritic and sulphatic forms of sulphur.

After the quartz reactor tube was redesigned and a computer-based controller was introduced, several samples of a control coal containing two weight per cent sulphur were pyrolysed to ascertain the reproducibility of the method. It was found that reproducibility was variable, apparently because of sample inhomogeneity. H_2S recovery was improved, however, by using flush gases containing hydrogen. They included water, methane and a mixture of helium and hydrogen.

Meanwhile, a critical assessment of results from using the Kiba Extraction technique led to the conclusion that previous claims about distinguishing pyritic and sulphatic sulphur may have been optimistic.

[2] A Coal Research Grants Program project.

Geostatistics[3]

COAL MINING RESEARCH COMPANY, DEVON

Geostatistics has been used successfully in the mineral industry to assess ore bodies accurately by analysing the spatial correlations present in exploration data. The technique has been successfully applied to the evaluation of coal deposits where the results of analysis enabled improved mine planning and enhanced the quality of coal production.

While the focus of the Alberta Coal Geology Project is on regional variation in coal quality, the objective of this project was to develop the capability of analysing coal quality variation at the deposit level. Localized knowledge obtained through geostatistical analysis enables better control of quality and consistency of mined coal. This enhances preparation plant efficiency.

This year, one professional from the Coal Mining Research Company was trained in the theory and applications of geostatistics so as to enhance the services of the company in identifying and developing applications in coal mining and preparation.

[3] An Institutional Research Program project.

Project Expenditures

During the fiscal year from April 1, 1987 to March 31, 1988, expenditures on approved research projects totalled $9 938 093, of which $4 588 933 was provided by the Alberta Office of Coal Research and Technology. The remainder, $5 349 160, or 54 per cent of the total, was contributed by the coal industry.

Funding contributions to approved projects are shown, by year, in Table 1. Contributions to coal-related research since April 1, 1977 are shown in Figure 1. The distribution of funding contributions for the past two years, and projected for 1988/89, is shown in Figure 2.

Table I: Funding Contributions to Approved Projects by Year ($)

Project Title	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	Projected Future Total	Total
Resource Evaluation													
Analysis of Coal-Bearing Strata Near Cadomin	-	507	15 762	3 731	-	-	-	-	-	-	-	-	20 000
Reflective Seismic Investigation of Western Canadian Coalfields	-	-	-	-	35 668	17 760	3 564	-	-	-	-	-	56 992
Surface Geophysics	-	-	-	-	-	-	-	96 915	112 053	124 500	-	-	333 468
VLF Geophysical Methods in Coal Exploration	-	-	-	-	-	-	-	4 426	10 420	-	-	-	14 846
Potential of Geophysical Techniques in Coal Exploration	-	-	-	-	-	-	-	-	69 470	-	-	-	69 470
Downhole Geophysical Characterization of Overburden	-	-	-	-	-	-	-	-	-	30 667	44 099	188 646	263 412
In-Seam Coal Characterization	-	-	-	-	-	-	-	-	-	93 111	143 713	-	236 824
3-D Structural Geometries	-	-	-	-	-	-	-	-	22 873	30 127	-	-	53 000
Seismic Modelling of Shallow Coalfields	-	-	-	-	-	-	-	-	-	24 723	7 720	38 207	70 650
Alberta Coal Geology Project	-	-	-	-	-	-	-	-	-	138 110	562 129	499 761	1 200 000
Subtotal Resource Evaluation	-	507	15 762	3 731	35 668	17 760	3 564	101 341	214 816	441 238	757 661	726 614	2 318 662
Mining													
Coal Mining Research	14 692	67 595	115 347	181 640	225 662	296 129	358 220	278 838	417 439	-	-	-	1 955 562
Support Design for Underground Cavities in Weak Rock	132 154	-	-	-	-	-	-	-	-	-	-	-	132 154
Creep Characteristics of Coal	-	-	-	-	-	-	14 439	2 020	-	-	-	-	16 459
Coal Mining in 2035	-	-	-	-	-	-	-	-	78 682	-	-	-	78 682
Geotechnical Properties of Overburden	-	-	-	-	-	-	-	-	71 501	-	-	-	71 501
Footwall Anchoring	-	-	-	-	-	-	-	-	-	81 246	57 853	-	139 099
Triaxial Test Development	-	-	-	-	-	-	-	-	-	103 503	-	-	103 503
Robotics for Mine Control	-	-	-	-	-	-	-	-	-	96 178	-	-	96 178
Mining 2035 Workshop	-	-	-	-	-	-	-	-	-	25 226	-	-	25 226
Non-Cable Vehicle Guidance	-	-	-	-	-	-	-	-	-	-	133 455	-	133 455
Lasers in Coal Mining	-	-	-	-	-	-	-	-	-	-	50 954	-	50 954
Ground Movements in Coal Mines	-	-	-	-	-	-	-	-	11 469	14 031	-	-	25 500
Time-Dependent Behaviour of Coal Measure Rocks	-	-	-	-	-	-	-	-	-	15 228	19 745	4 967	39 940
Deformation and Progressive Failure of Open-Pit Highwalls	-	-	-	-	-	-	-	-	-	44	71 934	12 724	84 702
Subtotal Mining	**146 846**	**67 595**	**115 347**	**181 640**	**225 662**	**296 129**	**372 659**	**280 858**	**579 091**	**335 456**	**333 941**	**17 691**	**2 952 915**
Preparation and Upgrading													
Coal Preparation Research	39 845	183 315	312 815	492 675	612 060	803 189	835 845	1 188 731	224 014	-	-	-	4 692 489
Coal Ash Monitoring System	-	13 555	24 185	25 130	8 763	-	-	-	-	-	-	-	71 633
Automedium Cyclones	-	-	-	-	22 929	34 842	37 940	-	-	-	-	-	95 711
Beneficiation of Coal by Agglomeration in Pipelines	-	-	-	49 944	60 947	74 523	22 220	-	-	-	-	-	207 634
Agglomeration of Low-Rank Alberta Thermal Coals	-	-	-	-	-	136 754	-	-	-	-	-	-	136 754

Project Title	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	Projected Future Total	Total
Coal Beneficiation Process	-	-	-	-	-	-	-	68 546	153 438	595 072	66 920	-	883 976
Agglomeration for Beneficiation	-	-	-	-	-	-	-	-	18 444	31 328	-	-	49 772
Numerical Analysis of Process Yield Losses	-	-	-	-	-	-	-	-	56 000	19 795	-	-	75 795
Properties of Thermally Dried Coal	-	-	-	-	-	-	-	-	99 459	45 000	-	-	144 459
Washery Optimization	-	-	-	-	-	-	-	-	-	93 876	127 102	-	220 978
Coal Comminution	-	-	-	-	-	-	-	-	-	54 466	-	-	54 466
Stabilization of Dried Coals	-	-	-	-	-	-	-	-	-	37 423	-	-	37 423
Advanced Processes for Low-Rank Coals	-	-	-	-	-	-	-	-	-	79 392	-	-	79 392
Preparation and Upgrading Assistance	-	-	-	-	-	-	-	-	-	705	41 295	-	42 000
Froth Flotation Study at Coal Valley	-	-	-	-	-	-	-	-	-	-	29 237	-	29 237
Moisture and Ash On-Stream Analyser	-	-	-	-	-	-	-	-	-	-	26 553	-	26 553
Recovery of Coal from Tailings	-	-	-	-	-	-	-	-	-	-	82 231	-	82 231
Coal Agglomeration Process Development	-	-	-	-	-	-	-	-	-	-	35 000	52 500	87 500
Agglomeration of Coking Coal	-	-	-	-	-	-	-	-	-	-	90 000	-	90 000
Fine Coal Technical Assistance	-	-	-	-	-	-	-	-	-	-	2 308	-	2 308
Subtotal Preparation and Upgrading	**39 845**	**196 870**	**337 000**	**567 749**	**704 699**	**1 049 308**	**896 005**	**1 257 277**	**551 355**	**957 057**	**500 646**	**52 500**	**7 110 311**
Combustion													
Prediction of Coal Combustibility	-	-	-	-	-	-	-	-	83 359	56 463	7 594	-	147 416
Combustion of Agglomerated Coal	-	-	-	-	-	-	-	2 061	22 950	8 325	-	-	33 336
IEA Coal Combustion Science	-	-	-	-	-	-	-	-	101 619	184 708	146 368	32 869	465 564
Combustion Program Planning	-	-	-	-	-	-	-	-	39 612	18 991	18 000	-	76 603
Combustion Characteristics of Alberta Coals	-	-	-	-	-	-	-	-	97 849	91 121	-	-	188 970
Combustion Process Research	-	-	-	-	-	-	-	-	25 215	125 000	-	-	150 215
Combustibility of Agglomerates	-	-	-	-	-	-	-	-	-	14 156	-	-	14 156
Influence of Porosity on Combustion	-	-	-	-	-	-	-	-	-	-	84 000	-	84 000
Combustibility of Upgraded Alberta Coals	-	-	-	-	-	-	-	-	-	-	115 000	-	115 000
Evaluation of Blending on Combustibility	-	-	-	-	-	-	-	-	-	-	36 000	-	36 000
Causes of Spontaneous Combustion of Western Canadian Coals	-	-	-	-	-	-	-	-	-	52 040	46 396	3 068	101 504
A Thermodynamic Model for Spontaneous Combustion of Coal	-	-	-	-	-	-	-	-	-	-	-	96 130	96 130
Subtotal Combustion	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**2 061**	**370 604**	**550 804**	**453 358**	**132 067**	**1 508 894**
Liquefaction													
ENR/ARC Coal Conversion Research	2 055	-	37 412	1 182 372	3 135 406	4 158 527	3 034 865	2 085 164	706 548	-	-	-	14 342 349
Coal Liquefaction Study	-	-	-	151 864	-	-	-	-	-	-	-	-	151 864
Hydroprocessing of Coal-Based Liquids	-	-	-	-	-	45 593	34 463	4 880	-	-	-	-	84 936
Supercritical Gas Extraction of Coal	-	-	-	-	-	30 611	31 208	5 473	-	-	-	-	67 292
Coal Liquefaction Feasibility Study	-	-	-	-	-	-	-	90 553	-	-	-	-	90 553
PYROSOL Process Review	-	-	-	-	-	-	-	-	7 006	-	-	-	7 006

Project Title	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	Projected Future Total	Total
New Liquefaction Processes	-	-	-	-	-	-	-	-	32 949	198 000	-	-	230 949
PYROSOL Process Development	-	-	-	-	-	-	-	-	-	2 282 650	603 461	1 382 389	4 268 500
Liquefaction Process Improvement	-	-	-	-	-	-	-	-	51 059	-	-	-	51 059
Liquefaction Process Evaluation	-	-	-	-	-	-	-	-	26 191	51 600	-	-	77 791
Chemistry of Coal Liquefaction	-	-	-	-	-	-	-	-	84 232	121 000	303 672	-	508 904
Secondary Upgrading	-	-	-	-	-	-	-	-	-	-	182 671	-	182 671
Functional Group Analysis of Coal Liquids	-	-	-	-	-	-	-	-	30 515	49 793	10 692	-	91 000
Isotopic Analysis of Co-processing Schemes	-	-	-	-	-	-	-	-	22 082	51 918	-	-	74 000
Supercritical Gas Extraction of Coal	-	-	-	-	-	-	-	-	-	27 588	45 617	9 070	82 275
Hydroprocessing of Coal-Derived Liquids	-	-	-	-	-	-	-	-	-	15 607	46 209	43 584	105 400
Liquefaction of Coal with Natural Gas	-	-	-	-	-	-	-	-	-	-	29 404	6 346	35 750
Isotopic Studies of Coal/Bitumen Co-processing Schemes	-	-	-	-	-	-	-	-	-	-	77 784	44 356	122 140
Molecular Interactions During Co-processing	-	-	-	-	-	-	-	-	-	-	-	106 400	106 400
Subtotal Liquefaction	**2 055**	**-**	**37 412**	**1 334 236**	**3 135 406**	**4 234 731**	**3 100 536**	**2 186 070**	**960 582**	**2 798 156**	**1 299 510**	**1 592 145**	**20 680 839**
Gasification													
Gasification of Western Canadian Coals	-	-	-	-	-	-	-	-	-	38 500	-	-	38 500
Fluidized Bed Gasification of Highvale Coal	-	-	-	-	-	-	-	-	-	-	64 201	-	64 201
Gasification Process Research	-	-	-	-	-	-	-	-	-	12 207	72 154	-	84 361
Gasification Properties of Alberta Coals	-	-	-	-	-	-	-	-	-	34 957	130 000	-	164 957
Gasification Behaviour of Alberta Coals	-	-	-	-	-	-	-	-	-	5 466	179 850	-	185 316
Gasification Laboratory Facilities	-	-	-	-	-	-	-	-	-	-	160 000	-	160 000
Economics of Coal Gasification	-	-	-	-	-	-	-	-	-	-	10 450	-	10 450
Corrosion in Gasification Systems	-	-	-	-	-	-	-	-	-	50 871	43 069	460	94 400
Subtotal Gasification	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**142 001**	**659 724**	**460**	**802 185**
Transportation													
Coal Slurry Pipeline Research	-	-	-	-	-	-	114 903	150 333	22 717	-	-	-	287 953
Coal Market Access Model	-	-	-	-	-	-	-	-	-	-	69 846	44 935	114 781
Coal-Oil Slurry Pipelining	-	-	-	-	-	-	-	-	-	-	204 331	1 423 329	1 627 660
Coal Slurry Technology	-	-	-	-	-	-	-	-	-	-	25 576	555 000	580 576
Coal/Oil/Natural Gas Transportation System	-	-	-	-	-	-	-	-	-	-	25 000	-	25 000
Subtotal Transportation	**-**	**-**	**-**	**-**	**-**	**-**	**114 903**	**150 333**	**22 717**	**-**	**324 753**	**2 023 264**	**2 635 970**
Environment													
Coal Conversion Waste-Water Treatment	-	-	-	-	-	30 000	57 890	-	-	-	-	-	87 890
Low NOxSOx Burner	-	-	-	-	-	-	-	-	-	50 028	-	-	50 028
Coal for Use in Enhanced Oil Recovery: Emission Control Technology	-	-	-	-	-	-	-	-	-	-	14 625	-	14 625
Coal Conversion Waste-Water Treatment	-	-	-	-	-	-	-	-	17 305	38 577	8 118	-	64 000
Subtotal Environment	**-**	**-**	**-**	**-**	**-**	**30 000**	**57 890**	**-**	**17 305**	**88 605**	**22 743**	**-**	**216 543**

Project Title	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	Projected Future Total	Total
Markets													
Production of Activated Carbon	-	-	-	32 364	7 077	-	-	759	-	-	-	-	40 200
Fuel Options for Enhanced Oil Recovery	-	-	-	-	-	-	-	-	15 000	-	-	-	15 000
Conversion from Oil to Coal Water Fuel	-	-	-	-	-	-	-	-	26 093	9 283	-	-	35 376
Coal Use in Enhanced Oil Recovery	-	-	-	-	-	-	-	-	-	17 995	13 777	-	31 772
Coal-Fired Steam Injection Boiler	-	-	-	-	-	-	-	-	-	-	28 619	113 881	142 500
Activated Carbon from Coal	-	-	-	-	-	-	-	-	-	31 738	57 997	10 265	100 000
Subtotal Markets	-	-	-	32 364	7 077	-	-	759	41 093	59 016	100 393	124 146	364 848
Other													
Coal Technology Information Centre	-	-	-	-	-	143 753	114 830	123 537	189 000	-	-	-	571 120
CTIC Review	-	-	-	-	-	-	-	16 997	-	-	-	-	16 997
Data Gathering for Research Planning	-	-	-	-	-	-	-	-	10 784	41 212	-	-	51 996
Geostatistics	-	-	-	-	-	-	-	-	-	-	40 958	-	40 958
Electrolysis of Coal Slurries	-	-	-	-	-	-	-	-	26 655	65 588	20 757	-	113 000
Distributed Chemical and Physical Properties of Coal	-	-	-	-	-	-	-	-	-	-	8 973	45 227	54 200
Sulphur Isotope Studies of Coal	-	-	-	-	-	-	-	-	-	-	25 119	38 081	*63 200
Magnetic and Electric Properties of Alberta Coals	-	-	-	-	-	-	-	-	-	-	40 397	69 053	109 450
Slurry Flow through Tees and Manifolds	-	-	-	-	-	-	-	-	-	-	-	113 000	113 000
Distribution of Oxygen in Low-Rank Coals	-	-	-	-	-	-	-	-	-	-	-	40 000	40 000
Electrolysis of Coal Slurries II	-	-	-	-	-	-	-	-	-	-	-	60 000	60 000
Subtotal Other	-	-	-	-	-	143 753	114 830	140 534	226 439	106 800	136 204	365 361	1 233 921
TOTAL COAL	188 746	264 972	505 521	2 119 720	4 108 512	5 771 681	4 660 387	4 119 233	2 984 002	5 479 133	4 588 933	5 034 248	39 825 088

Figure 1: Research Expenditure on Approved Projects (excluding Coal Research Centre, Devon).

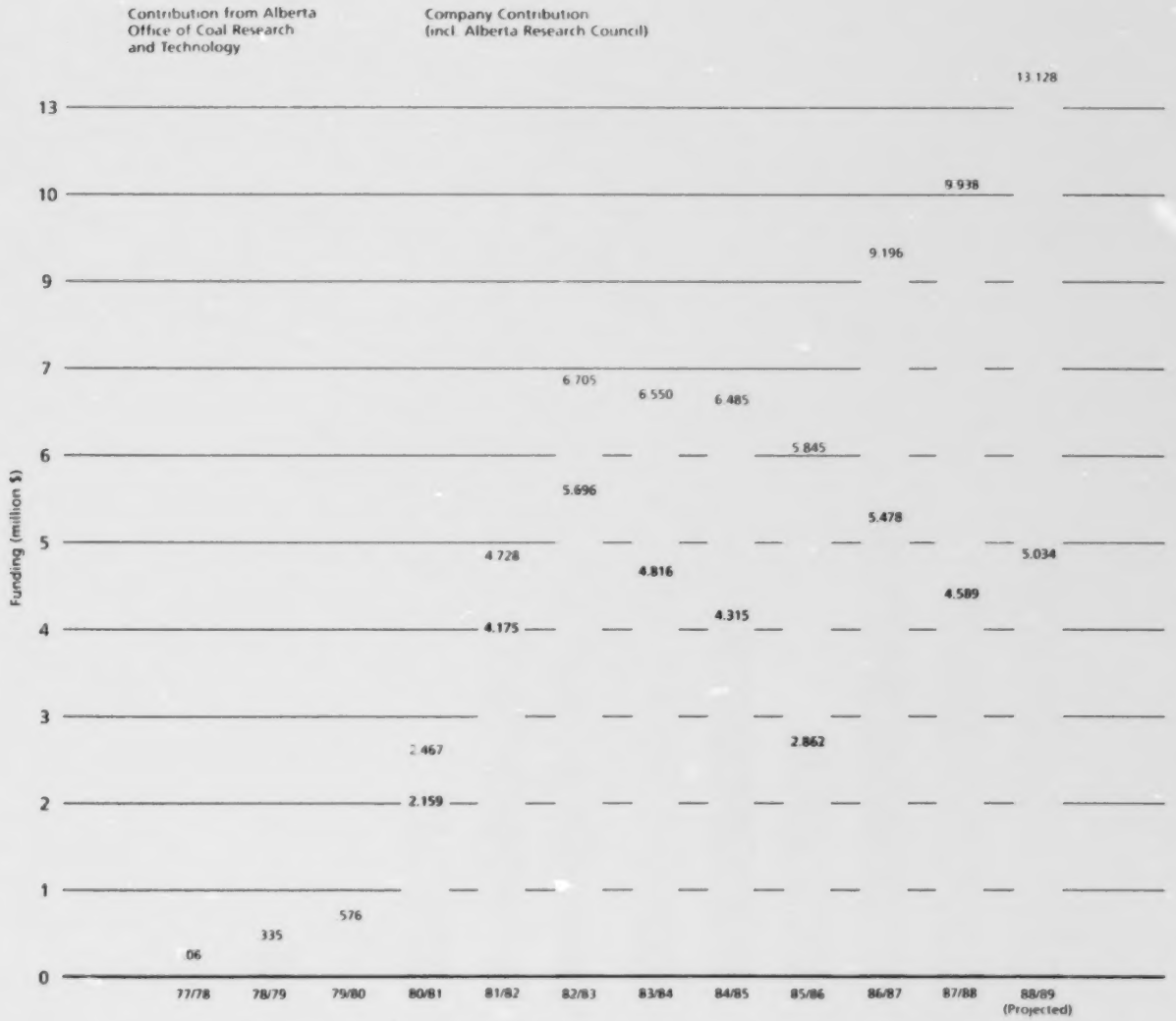
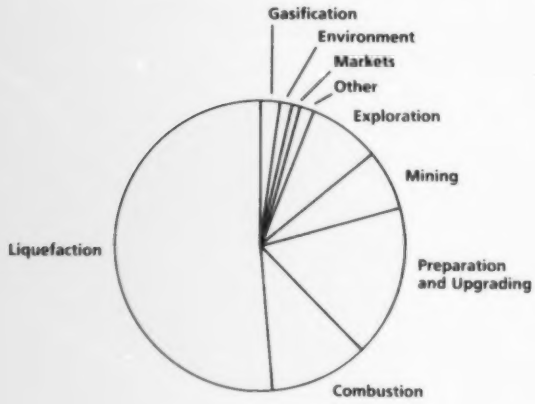
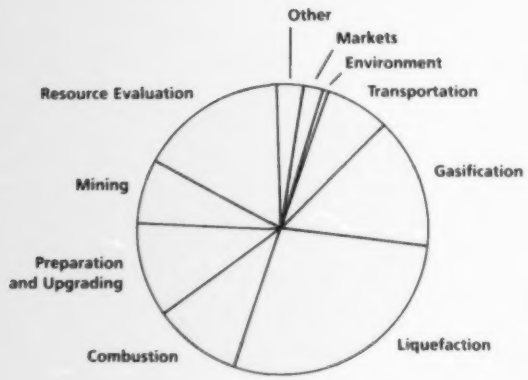


Figure 2: Distribution of Alberta Office of Coal Research and Technology Funding Contributions.

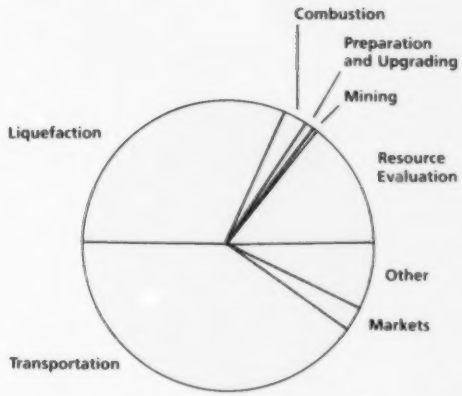
1986/87



1987/88



1988/89 (Projected)



Appendix

Strategic Research Program

The Government of Alberta believes that private sector companies should be primarily responsible for ensuring the economic development of the province. Similarly, Alberta's coal industry is expected to take the lead in developing and marketing coal resources, as well as identifying and managing the coal resources needed to improve the industry's competitive position. The role of the Office, other government agencies, universities and research organizations is to support the private sector in achieving appropriate coal-related technological developments.

Therefore, several coal research projects have been funded jointly by industry and the Office, with technical support sometimes provided by other research organizations.

Projects completed or under way are as follows:

Project	*Researcher*	*Status*
Resource Evaluation		
Surface Geophysical Coal Exploration	TransAlta Utilities Corporation and Others	Completed in 1986/87
Very Low Frequency Geophysical Methods in Coal Exploration	Smoky River Coal Limited	Completed in 1985/86
Downhole Geophysics	TransAlta Utilities Corporation and Others	Continuing
Mining		
Footwall Anchoring	Smoky River Coal Limited	Completed in 1987/88
Preparation and Upgrading		
Froth Flotation Study at Coal Valley	Luscar Sterco (1977) Ltd.	Completed in 1987/88
Coal Beneficiation Process	Gulf Canada Corporation and Unocal Canada	Continuing
Agglomeration of Subbituminous Coal	Manalta Coal Ltd.	Completed in 1986/87
Agglomeration of Coking Coal	Smoky River Coal Limited	Completed in 1987/88
Combustion		
Smoky DENSECOAL Combustion Tests	Monenco Consultants Ltd.	Completed in 1985/86
Prediction of Coal Combustibility	Esso Resources Canada Limited	Completed in 1987/88
International Energy Agency Coal Combustion Science	Netherlands Energy Research Foundation	Continuing
Combustion of Agglomerated Coal	Luscar Ltd.	Completed in 1985/86

Liquefaction		
Coal Liquefaction Feasibility Study	Contar Systems Engineering Ltd. and Others	Completed in 1984/85
Synthetic Fuels Program	SRI International	Completed in 1984/85
Economic Evaluation of Coal/Oil Co-processing	HRI Inc.	Completed in 1984/85
PYROSOL Process Review	Canadian Utilities Ltd. and Luscar Ltd.	Completed in 1985/86
PYROSOL Process Development	CCLC Technologies Inc. (now Canadian Energy Developments Inc.)	Continuing
Gasification		
Gasification of Western Canadian Coals	TransAlta Utilities Corporation and Others	Completed in 1986/87
Fluidized Bed Gasification of Coals	TransAlta Utilities Corporation and Others	Completed in 1987/88
Economics of Coal Gasification	Alberta Power Limited and Others	Completed in 1987/88
Transportation		
Coal Slurry Pipeline Research	Pembina Resources Ltd.	Completed in 1984/85
Coal Market Access Model	Trimac Consulting Services Ltd.	Continuing
Coal-Oil Slurry Pipelining	Unocal Canada Limited	Continuing
Coal/Oil/Natural Gas Transportation System	CERI Energy Research Ltd.	Completed in 1987/88
Coal Slurry Technology	Salzgitter Industriebau GmbH and Others	Continuing
Environment		
Low NOxSOx Burner	TransAlta Utilities Corporation	Completed in 1986/87
Coal for Use in Enhanced Oil Recovery: Emission Control Technology	Esso Resources Canada Limited	Completed in 1987/88

Markets		
Imported Steam Coal Demand	The Institute of Energy Economics (Japan)	Completed in 1984/85
Conversion from Oil to Coal-Water Fuels	Smoky River Coal Limited	Completed in 1985/86
Fuel Options for Enhanced Oil Recovery	L.A. Smith Consulting and Development Ltd.	Completed in 1985/86
Coal Use in Enhanced Oil Recovery	Luscar Ltd. and Others	Completed in 1987/88
Coal-Fired Steam Injection Boiler	Fording Coal Limited	Continuing
Other		
Technical Information Needs	Crozier Information Resources Consulting Ltd.	Completed in 1985/86

Institutional Research Program

The Institutional Research Program comprises a significant number of projects carried out by two non-profit research organizations: the Alberta Research Council and the Coal Mining Research Company.

a) Alberta Research Council

Since it was established in 1921, the Alberta Research Council (ARC) has included energy resources research among its many scientific areas of interest. In recent years, this provincial Crown corporation has been actively involved in a broad range of coal-related investigations carried out by the Coal and Hydrocarbon Processing Department.

In recognition of ARC's expertise and the work this agency conducts for industry, it was decided that the aims of the Office and the Alberta Research Council could best be served if the latter undertook a range of projects in coal liquefaction, combustion and gasification. In addition, the multi-year Alberta Coal Geology Project was initiated in 1986/87 by the ARC as a continuation of a coal exploration program begun in 1974. This project, which is jointly funded by the Office and the ARC, is primarily concerned with evaluating coal quality as it relates to uses for coal. Also, from 1980 to 1984, a coal agglomeration program was carried out at the ARC (initially in co-operation with the University of Alberta) with funding from A/CERRF (administered through the Office since 1984). This led to a major development of the coal agglomeration process supported by the Electric Power Research Institute and several companies and governments. Currently, the Office is participating in one phase of this latter project.

Following a major coal liquefaction project carried out between 1979 and 1985 by the ARC, several liquefaction projects were funded by the Office.

This research is aimed at obtaining a better understanding of the chemical reactions taking place when coal and heavy oil are co-processed to form products capable of being converted to liquid transportation fuels. This includes studies of upgrading processes required to transform the co-processing products to refinery-compatible feedstocks. The Office is also funding research investigations at the ARC that complement private sector activities related to co-processing. Projects funded thus far are as follows:

New Liquefaction Processes	Completed in 1986/87
Liquefaction Process Improvements	Completed in 1985/86
Liquefaction Process Evaluation	Completed in 1986/87
Chemistry of Coal Liquefaction	Continuing
Secondary Upgrading	Continuing

The principal objective of the coal combustion studies at the Alberta Research Council is to enhance the expertise of ARC staff in using the latest equipment and in becoming familiar with world-wide developments in this active research field. Projects carried out in this area include the following:

Combustion Process Research	Completed in 1986/87
Combustion Characteristics of Alberta Coals	Completed in 1986/87
Combustion Program Planning	Completed in 1987/88
Combustibility of Agglomerates	Completed in 1986/87
Influence of Porosity on Combustion	Completed in 1987/88
Combustibility of Upgraded Alberta Coals	Continuing
Evaluation of Blending on Combustibility	Completed in 1987/88

Coal gasification is receiving considerable attention world-wide because it can cleanly produce electrical energy from coal, and is less expensive than conventional, coal-fired thermal power processes fitted with flue gas desulphurization equipment. Therefore, it was decided that the establishment of Alberta-based coal gasification expertise and facilities would be essential for Alberta's coal producers and users to exploit any market opportunities made possible by coal gasification developments in Canada and overseas.

Consequently, the Office is funding projects at the Alberta Research Council to:

- facilitate development of expertise on coal gasification research; and
- investigate the suitability of Alberta coals for use in various coal gasification technologies.

Projects pertaining to these objectives are:

Gasification Process Research	Completed in 1987/88
Gasification Properties of Alberta Coals	Completed in 1987/88
Gasification Behaviour of Alberta Coals	Completed in 1987/88
Gasification Laboratory Facilities	Completed in 1987/88

b) Coal Mining Research Company

The Coal Mining Research Company (CMRC) is a private, non-profit company established in 1977 to provide industry and government with research, development and technology transfer services related to the mining and beneficiation of coal. Although the company was financed initially by A/CERRF (administered through the Office since 1984), an increasing proportion of its funding in recent years has been received from contract research work performed for mining companies, mining consultants and various government agencies.

Several research projects funded by the Office were carried out by CMRC as follows:

Resource Evaluation

Potential of Geophysical Techniques for Coal Exploration	Completed in 1985/86
In-Seam Coal Characterization	Completed in 1987/88

Mining

Geotechnical Properties of Overburden	Completed in 1985/86
Coal Mining Research	Completed in 1985/86
Triaxial Test Development	Completed in 1986/87
Coal Mining in 2035	Completed in 1985/86
Mining 2035 Workshop	Completed in 1986/87
Robotics for Mine Control	Completed in 1986/87
Non-Cable Vehicle Guidance	Completed in 1987/88
Lasers in Coal Mining	Completed in 1987/88

Preparation and Upgrading

Coal Preparation Research	Completed in 1985/86
Coal Comminution	Completed in 1986/87
Preparation and Upgrading Assistance	Completed in 1987/88
Washery Optimization	Completed in 1987/88
Moisture and Ash On-Stream Analyser	Completed in 1987/88
Numerical Analysis of Process Yield Losses	Completed in 1986/87
Advanced Processes for Low-Rank Coal	Completed in 1986/87
Properties of Thermally Dried Coals	Completed in 1986/87
Stabilization of Dried Coal	Completed in 1986/87
Recovery of Coal from Tailings	Completed in 1987/88
Fine Coal Cleaning	Completed in 1987/88

Other

Data Gathering for Research Planning	Completed in 1986/87
Geostatistics	Completed in 1987/88

Coal Research Grants Program

One of the aims of the Office is to encourage scientific excellence in coal-related fundamental research, with the objective of placing Canadian coal technology in a position of world leadership.

To help reach this goal, the Coal Research Grants Program was established to provide funding to university researchers, and the Coal Research Technical Panel was formed to evaluate research grant applications. The panel[1] comprises representatives from the three Alberta universities, industry, the Alberta Research Council, the Coal Mining Research Company, The Coal Association of Canada and the Office.

The first competition under this program was held in January 1985. Since then, 19 projects have been initiated, of which eight were completed during 1987/88. These projects and their status are as follows:

Project	*Researcher*	*University*	*Status*
Resource Evaluation			
Structural Geometry of Imbricated Thrust Sheets	Dr. D.A. Spratt	University of Calgary	Completed in 1986/87
Seismic Modelling of Shallow Coalfields	Dr. D.C. Lawton	University of Calgary	Completed in 1987/88
Mining			
Ground Movements in Coal Mines	Dr. D.M. Cruden	University of Alberta	Completed in 1986/87
Time-Dependent Behaviour of Coal Measure Rocks	Dr. R. Day	University of Calgary	Completed in 1987/88
Deformation and Progressive Failure of Open-Pit Highwalls	Dr. N.R. Morgenstern	University of Alberta	Continuing
Combustion			
Causes of Spontaneous Combustion of Western Canadian Coals	Dr. F.W. Bachelor	University of Calgary	Completed in 1987/88
Liquefaction			
Functional Group Analysis of Coal Liquids	Dr. M.R. Gray	University of Alberta	Completed in 1987/88
Isotopic Studies of Coal/Bitumen Co-processing	Dr. K. Muehlenbachs	University of Alberta	Completed in 1986/87
Supercritical Gas Extraction of Coal	Dr. N. Berkowitz	University of Alberta	Continuing

[1] Coal Research Technical Panel members in 1987/88 were: K.E. Cooper (Chairman), D. Spratt, A. Hardin, E. Haniuk, D. Axelson, N. Berkowitz, R.T. Marshall, R. Chopiuk and E.J. Barry.

Hydroprocessing of Coal-Derived Liquids	Dr. I.G. Dalla Lana	University of Alberta	Continuing
Liquefaction of Coal with Natural Gas	Dr. M.R. Gray	University of Alberta	Continuing
Isotopic Studies on Coal/Bitumen Co-processing Schemes	Dr. K. Muehlenbachs	University of Alberta	Continuing
Gasification			
Corrosion in Gasification Systems	Dr. W.J.D. Shaw	University of Calgary	Completed in 1987/88
Environment			
Coal Conversion Waste-Water Treatment	Dr. S.E. Hrudey	University of Alberta	Completed in 1987/88
Markets			
Activated Carbon From Coal	Dr. E.L. Tollefson	University of Calgary	Completed in 1987/88
Other			
Electrolysis of Coal Slurries	Dr. V.I. Birss	University of Calgary	Completed in 1987/88
Distributed Chemical and Physical Properties of Coal	Dr. P.J. Crickmore	University of Alberta	Continuing
Sulphur Isotope Studies of Coal	Dr. R.H. Krouse	University of Calgary	Continuing
Magnetic and Electric Properties of Alberta Coals	Dr. H.A. Buckmaster	University of Calgary	Continuing

Persons wishing to receive future Office publications or requiring more information about Office projects and programs, should contact:

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Publications currently available are:

Alberta Coal: Energy for the World. 27 pages, August 1987.

Annual Review 1984/85, Alberta Office of Coal Research and Technology. 24 pages, 1985.

Annual Review 1985/86, Alberta Office of Coal Research and Technology. 26 pages, 1986.

Annual Review 1986/87, Alberta Office of Coal Research and Technology. 32 pages, 1988.

An Economic Analysis of Coal Pipeline Systems. 6 pages, January 1987.

Opportunities to Use Coal in Enhanced Oil Recovery. 8 pages, May 1988.

Development of an Agglomeration Process to Beneficiate and Transport Alberta Coals. 14 pages, June 1988.

Gasification of Western Canadian Coals. 14 pages, June 1988.

Coal Research Centre, Devon. 10 pages, August 1988.

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